

Demand-Side Feasibility of eCooking on Minigrids: Evidence from Sheder Refugee Camp, Ethiopia

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LIST OF ACRONYMS

ACRONYM	FULL TERM
CRRF	Comprehensive Refugee Response Framework
EPC	Electric Pressure Cooker
ETB	Ethiopian Birr
FGD	Focus Group Discussion
GWh	Gigawatt-hour
HumEn	Humanitarian Energy PLC
HH	Household
HHs	Households
ICS	Improved Cook Stove
IDP	Internally Displaced Person
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
IR	Infrared (Stove)
kWh	Kilowatt-hour
MECS	Modern Energy Cooking Services
NGO	Non-Governmental Organization
PAYG	Pay-As-You-Go
PLC	Private Limited Company
PV	Photovoltaic
SDG	Sustainable Development Go
TABLE	Testing Adaptive Business Models for Electric Cooking
UNHCR	United Nations High Commissioner for Refugees
USD	United States Dollar
WTP	Willingness to Pay

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Introduction

This study evaluates the technical, economic, and sociocultural feasibility of transitioning households and small food businesses in Sheder Refugee Camp, Ethiopia, from biomass-based cooking to electric cooking (eCooking) using appliances powered by a 254kW solar minigrid.

The study enrolled 76 users (53 treatment households, 19 control households and 4 small restaurant businesses) and tested three different eCooking appliances: Electric Pressure Cookers (EPCs), induction stoves and infrared stoves. Extensive datasets were collected through surveys, metered stove use, metered household electricity use, cooking diaries and focus group discussions. The research employed a three-phase mixed methods design starting with a baseline assessment of existing cooking practices, a transition phase in which the appliances were provided under normal electricity tariff conditions, and a final phase in which electricity for cooking was made temporarily free to observe the limits of demand under the removal of affordability constraints.

Summary of Findings

There was near exclusive reliance on woodfuels at baseline. Charcoal was the most used fuel providing the primary source of cooking energy for 87% of surveyed households. It was often stacked with firewood, which was the main source of cooking energy for the remainder of participants. Cooking practices were dominated by long-boil staple foods such as rice, beans, pasta, tea, and sauces, resulting in high fuel demand. Over 90% of households reported poor or very poor indoor air quality during cooking, frequently citing respiratory issues, eye irritation and thermal comfort challenges when cooking.

The results showed strong latent demand for eCooking. In Phase 2, when households were paying for the electricity they used, the eCooking appliance displaced around a third of cooking activities, with the infrared stove being the most used (39% of cooking events corresponding to an average of 1.25 kWh/household/day), closely followed by the EPC (37%, 0.24 kWh/HH/day) and the induction stove (29%, 0.66 kWh/HH/day). In Phase 3, when electricity was made free, the infrared stove almost completely displaced all other fuels (used for 93% of cooking events and 4.69 kWh/HH/day), whilst use of the EPC (65%, 0.69 kWh/HH/day) and induction stove (60%, 1.65 kWh/HH/day) both doubled. The higher adoption of infrared stoves was due to their

compatibility with traditional cookware and ability to support culturally important foods, including injera, and large pots. EPCs were valued for efficiency in long boil cooking but were constrained by their 6–8 litre capacity for larger sized households. Induction stoves faced persistent barriers due to cookware incompatibility and perceived impacts on taste and versatility.

The introduction of the eCooking appliance resulted in financial savings for all users even under standard tariff rates. Participants consistently reported significant time savings, cleaner cooking environments, and reduced smoke exposure when using eCooking appliances. These benefits translated into improved household wellbeing, particularly for women responsible for cooking.

Businesses showed even higher charcoal dependence than households, with 92% of restaurants relying on this fuel. After the introduction of the appliances, they consistently recorded higher daily electricity consumption for cooking than households (averaging at 1.23 kWh/business/day in Phase 2 and 2.87 kWh/business/day in Phase 3), reflecting both larger cooking volumes and a stronger readiness to shift core cooking tasks to electric appliances. However, free electricity had less of an adoption impact for businesses than for households. This was because commercial-scale pots required for preparing large batches of food were often incompatible with the study appliances, forcing continued reliance on charcoal for peak-demand cooking.

A rough willingness-to-pay analysis revealed a gap between stated willingness to pay and actual purchasing behaviour. While the median stated willingness to pay for an EPC was approximately 1,500 birr (compared to an actual cost exceeding 10,000 birr), 96% of participants purchased appliances for 2000 birr (80% subsidy). Pay as-you-go was chosen as the preferred business and financing model by 84% of users, indicating strong demand for structured payment mechanisms that are decoupled from electricity payments.

Conclusions

The study demonstrates that eCooking is both technically feasible and socially acceptable in Sheder's refugee camp context. The Phase 2 consumption figures are of the same magnitude as urban grid-based eCooking interventions elsewhere in sub-Saharan Africa. This important and surprising finding contradicts widely held assumptions about the unviability of market-based clean cooking interventions in refugee settings. When upfront cost and design barriers are addressed, electric cooking can dramatically reduce charcoal use, improve health outcomes and reduce fuel expenditure. While offering the least savings in cooking cost due to being the most inefficient among the tested stove options, infrared stoves hold the strongest scalability potential due to compatibility with traditional foods and existing cookware. However, successful scale up requires affordable appliance financing, context appropriate stove design, and strong after sales and supply chain support.

2. Background

Cooking in displaced settings: The need for an urgent shift to clean and modern options

Progress has been critically slow in providing everyone with access to modern, safe, clean, and affordable cooking energy. Globally, there are 2.1 billion people who still do not have access to clean, modern, safe, and affordable energy cooking services [1], a number which includes four-fifths of the 8.7 million refugees and internally displaced people (IDPs) who have been resettled in camp, rural, peri-urban or urban settings alongside host communities [2], [3]. Having fled their homes to escape from conflict, persecution, or disasters, this population faces severe challenges in accessing energy, with limited access to electricity and reliance on polluting fuels (such as kerosene, firewood, charcoal, and other biomass) burned in inefficient stoves for cooking (ibid.). Widespread reliance on biomass results in a range of extensive and damaging health, livelihoods, climate, environment and gender impacts [4].

Sheder camp background

The Sheder Refugee Camp was established in 2008 by the Government of Ethiopia and the United Nations High Commissioner for Refugees (UNHCR) [5] and rapidly emerged as a critical humanitarian response to protracted instability in Somalia. Located in Ethiopia's Somali Regional State (Fafan Zone), approximately 50 km northwest of Jijiga and near the Somaliland border, the camp occupies a semi-arid landscape within an agro-pastoralist host community. Its population expanded significantly during the 2011 Horn of Africa famine and subsequent regional conflicts, including secondary displacements of refugees returning from Yemen after 2015. As of 2024, Sheder hosts approximately 14,000 registered refugees, predominantly from Somalia's Gadabuursi clan (Aadan Yoonis subclan). Many of the households have resided in the camp for over a decade, reflecting a context of protracted displacement.



Figure 1: Photo of a street in Sheder.

The camp operates within Ethiopia's progressive refugee policies under the Comprehensive Refugee Response Framework (CRRF), which grants refugees access to work, health, education, and an out-of-camp policy to allow them to benefit from existing opportunities to become self-reliant [6]. However, despite the strides made in policy and legal framework, poor implementation has meant that refugee integration has barely progressed, and many Somali refugees remain in the camps without work permits. Therefore, nearly half (41%) of the residents rely primarily on humanitarian aid, while the others primarily engage in daily casual labor (22%) or operate small businesses (20%) [7]. This means that refugees primarily depend on monthly food ration cards by the UNHCR [5].

The preferred staple foods in the Sheder camp are rice, sauces, spaghetti, beans, and stew, with rice and beans taking the longest time to prepare [8]. The households also frequently consume a form of flat bread called injera, which is usually baked on a small (25 cm diameter) blackened aluminium plate (mitad) over an open fire with fuelwood or using an electric mitad. Freely collected firewood was the primary source of cooking fuel in the early days of the camp. However, a growing shortage of firewood has shifted reliance to charcoal made in the surrounding regions and transported to the camp by camel or donkey. A Mercy Corps survey has confirmed that households using charcoal spend on average between USD 36 to 90 on the fuel in a month, depending on the household size. There is widespread use of a charcoal and firewood-compatible improved cook stove (ICS) (BURN Manufacturing's Jiko Koa stove), which are purchased and imported from the border town of Wajaale in Somaliland. Priced at 65 USD, the stove is much more expensive than traditional, locally available stoves, but Mercy Corps assessments reported that the premium price could be paid off in less than 6 months through fuel savings⁵.



Figure 2: a selection of stoves from Sheder including a) a traditional firewood stove; (b) a firewood mitad; (c) a Jiko Koa ICS; (d) a kerosene stove; (e) a three stone fire.

Potential for eCooking in Sheder

Although the government has encouraged electric cooking (eCooking) as a modern, safe, and clean cooking option since the 1970s to utilise excess electricity and lessen the environmental effects of biomass, its adoption has remained low, at only 4.1% [9]. Barriers include an unreliable grid electricity service, a lack of access to sufficient electricity for eCooking, low affordability, cultural attachment to traditional biomass fuels, and limited awareness of alternatives (ibid.). The Mercy Corps team's preliminary research discovered that there is limited availability of eCooking appliances locally (Sheder), but all kinds of stoves are available at Jigjiga (62 Km from Sheder) and Wuchale Market in Somaliland (18 Km from Sheder). A study utilizing panel data found that the adoption of eCookstoves is hinged on the affordability of electricity prices, access to credit, and the cost of firewood (ie, higher cost would facilitate transition to eCooking) [10].

However, with government plans to increase electricity access from currently over 50% to 100% by 2025 [11], and growing enabling environment for eCooking adoption (namely low electricity tariffs, declining availability of biomass, increasing prices of biomass, growing domestic eCooking appliance manufacturing), the use of eCooking can be further scaled to unlock its great potential in Ethiopia. A mass transition to eCooking would bring substantial benefits pertaining to health (903 disability-adjusted life years avoided per year), gender (132 million hours of women's time saved from fuelwood search per year), environment (0.4 million tonnes reduction in unsustainable wood harvest per year), climate (2.2 million tonnes carbon dioxide equivalent emissions reduced per year), and economy (14 months payback for eCooking appliances, and 517 GWh demand for electricity stimulated) [9].

Similar benefits could also be felt across Ethiopia's many refugee camps, including Sheder. In 2024, Humanitarian Energy PLC (HumEn), a private Ethiopian company that provides renewable energy solutions for underserved communities, opened a flagship \$2.6 million solar PV-diesel hybrid minigrid in Sheder [12], [13]. Since its commissioning, more than 1,500 households, businesses and social institutions in the refugee and host communities of Sheder have been connected to the grid, receiving Tier 4 electricity access (ibid.). The minigrid addresses a substantial gap in energy access in the Somali Region, which as of 2022, had only 10% of its households connected to the national electricity grid [14]. One in five customers of the minigrid use it for income-generating activities, particularly refrigeration of goods, and almost all of whom have reported an increase in their income as a result (ibid.).

The HumEn minigrid adopts a market-based approach, reflecting broader trends in transitioning humanitarian sites toward sustainable development hubs [15]. The minigrid charges 0.15\$/kWh (19 birr/kWh, daytime tariff) and 0.18\$/kWh (24 birr/kWh, night-time tariff).

Although the minigrid tariff is substantially higher than that of the national grid, the reality is that the Sheder community cannot benefit from the national grid; the refugee community are not allowed to connect to it, and the host community (who can connect) face issues with unreliability and limited availability of the grid. Thus, prior to the advent of the minigrid, the main source of electricity in Sheder was diesel. The minigrid has an estimated monthly electricity bill of around \$8 for a household with three light bulbs, a TV, a refrigerator, and a washing machine; half the cost of what the refugees would pay for two hours of diesel-powered electricity [12], [13]. Indeed, 90% minigrid users have reported a reduction in energy spending, according to a report by 60 Decibels commissioned by Mercy Corps, the major shareholder of Humanitarian Energy Plc [7].

The reception of the minigrid has been overwhelmingly positive. Electricity from the Sheder minigrid is primarily used to run appliances like mobile phones, lamps, radios, and televisions, and has disrupted almost all the usage of prior energy sources, such as torches, generators, kerosene lamps, solar lanterns, and candles. For almost all beneficiaries (94%), this was their first access to a grid system, and two-thirds of them reported resultant quality of life improvements due to improved lighting, the ability to use a wider range of appliances, the ability to charge mobile phones, and improved perceptions of safety [7].

However, as is common with minigrids, users complained of power outages that affect electricity access, delay power restoration after payment, and slow technical support [7]. The 60 Decibels report identified particular challenges arising from communication issues with the smart meter arising from the suppliers' side. Users have reported a poor tracking of remaining balance. However, the system provides two available balance tracking options which they haven't utilized.

Importantly, prior to the pilot described in this report, electricity use on the minigrid remained limited to non-cooking purposes, except for a handful of businesses and selected HHs.

Experiences with minigrid eCooking elsewhere

The uptake of eCooking can be affected by a range of various, interacting factors. Years of experience of the UK-aid funded Modern Energy Cooking Services (MECS) programme suggest that eCooking adoption can be hindered by (generally inaccurate) perceptions of and overall high cost, steep learning curve for new appliances, differences in taste of food cooked using eCooking methods, safety concerns when using eCooking appliances, the reluctance of male head of households to purchase eCooking appliances, and the lack of awareness, availability, and after-sales services for energy-efficient appliances [16].

Implementing eCooking interventions on minigrid can be especially challenging as they can cause issues with grid stability, voltage swings, and capacity constraints, particularly during periods of peak demands [17]. In 2022, MECS funded seven projects to develop business plans for integrating eCooking into planned or existing minigrids. A report sharing learnings across the project portfolio highlighted how eCooking increased household electricity demand and in turn community-wide demand, translating into enhanced revenues for minigrid operators. However, it also increased peak demand, upgrades to the minigrid infrastructure were frequently required to accommodate this peak. In some cases, the additional capital expenditure and operating costs made eCooking economically unviable. The report concluded by highlighting the context-specific suitability of minigrid based eCooking and how its feasibility varies widely according to both the minigrid's configuration and the cooking ecosystem in the community [18].

Table 1 shows measured loads from on and off-grid eCooking interventions to provide benchmarks of potential loads on the Sheder minigrid. It shows that household daily energy consumption tended to be 1-2 kWh per day with most of the data coming from electric pressure cooker pilots. However, these numbers are substantially higher than those observed by the authors outside of pilot settings, where real-world consumption has tended to be 0.2-0.7 kWh per day on EPCs and 0.8-1 kWh per day on induction stoves.

Table 1: Summary of electricity consumption from eCooking studies.

			Cooking device type	Household daily energy consumption (kWh)	Ref.
Urban	Zambia	Using 100% electricity for cooking	EPC	1.63	[19]
		Using 90% electricity for cooking plus fuel stacking	EPC	1.1	[19]
	Tanzania	Using 100% electricity for cooking	EPC	2.06	[19]
		Using 90% electricity for cooking plus fuel stacking	EPC	1.44	[19]
	Kenya	Using 100% electricity for cooking	EPC	1.4	[19]
		Using 90% electricity for cooking plus fuel stacking	EPC	0.96	[19]
Rural	Nepal	Using 100% electricity for cooking	Induction hob	1.58	[20]
	Tanzania	Using 100% electricity for cooking (MECS modelling tool)	EPC and Induction hob	1.75–2.2	

Motivation and project aims: Advancing eCooking adoption in Sheder refugee camp

The persistent reliance on biomass fuels for cooking in displacement settings like the Sheder camp constitutes a critical humanitarian and developmental challenge with multifaceted negative consequences. Despite the successful deployment of Ethiopia's first commercially licensed solar PV minigrid by HumEn in Sheder, refugees continue to depend on inefficient and hazardous biomass stoves. This report presents results from the Testing Adaptive Business Models for Electric Cooking (TABLE) program, which aimed to assess the socio-cultural compatibility, economic affordability, and technical feasibility of eCooking integrated with the HumEn minigrid in Sheder. The core objectives of the project are:

- 1. To assess the technical performance and user acceptance of different eCooking technologies.** The study evaluated the suitability of three appliance types, namely Electric Pressure Cookers (EPCs), Infrared stoves, and Induction stoves, for preparing local staple foods within the camp. It measured actual energy consumption, cooking times, and gathered user feedback on ease of use, safety, and food quality.
- 2. To evaluate the economic viability and adoption patterns of eCooking under real market conditions.** The study quantified changes in household fuel expenditure and time use when participants paid the standard minigrid tariff for cooking electricity. It also measured the latent demand for eCooking by providing a period of free electricity, observing shifts in usage and fuel stacking behavior.
- 3. To understand the key drivers, barriers, and willingness-to-pay for eCooking.** Through surveys and focus group discussions, the research identified the primary factors influencing adoption, including appliance design limitations, cultural preferences, maintenance concerns, and affordability. It assessed households' and businesses' stated willingness to pay for different appliances and their preferred acquisition models.
- 4. To inform scalable delivery and business models.** Based on observed adoption patterns, purchasing decisions at subsidised prices, and user preferences, the study aimed to provide actionable insights for designing feasible, context-appropriate models for financing and distributing eCooking solutions in Sheder and similar humanitarian settings.

3. Methodology

3.1 Study design and phases

The TABLE study draws upon a mixed-methods quasi-experimental design structured across three sequential phases, each with specific objectives and data collection protocols:

- **Phase 1 - Baseline Phase:** this established a detailed understanding of the status quo. Prior to any intervention, researchers documented existing cooking practices, fuels used, fuel procurement strategies, associated expenditures, time allocation for meal preparation and prior experiences with/perceptions of electric cooking. This phase provided critical contextual data against which all subsequent changes could be measured.
- **Phase 2 – Intervention Phase:** three types of appliances, electric pressure cookers (EPCs), induction stoves, and infrared (IR) stoves, were distributed to treatment groups, with each. A control group continued using their traditional cooking methods. This phase aimed to evaluate adoption patterns, user proficiency, and perceived utility of the appliances under the camp's standard electricity tariff. Concurrently, it allowed for an initial assessment of the minigrid's technical capacity to support incremental eCooking load without destabilisation.
- **Phase 3 – eCooking Phase:** this phase tested a subsidy intervention by providing participants in the treatment group with free electricity for a predetermined period. The principal aim of this phase was to remove the direct cost barrier of electricity consumption, thereby observing the maximum potential uptake of eCooking when economic constraints are minimised. This design facilitated an examination of whether households would fully transition to eCooking or maintain a mix of fuels ("stacking"), and it provided crucial data on the peak demand impact of widespread eCooking on the minigrid's infrastructure.

3.2 Participants and sampling

The study population was defined as households and small food vendors in Sheder camp that were both connected to the Humanitarian Energy PLC minigrid and had at least one literate adult member capable of engaging with the research tools. A purposive sampling strategy was employed to ensure participants met these criteria.

A total of 76 participants/users were enrolled into the household cohort. These were subsequently randomized into four groups using three eCooking appliances (Figure 3):

1. **Electric Pressure Cooker (EPC) group:** n=18 participants. Provided with one Sonifer EPC of either 6 litre (1kW, \$105) or 8 litre (1.35kW, \$110) capacity. The EPCs had a digital touch display with multiple pre-programmed cooking options.
2. **Induction Cooker group:** n=17 participants. Provided with one single-burner Smur fett induction stove each (2kW, \$27) and two accompanying induction-compatible pots (\$32). The induction stoves had a glass-ceramic panel, touch control and a two-hour timer.
3. **Infrared Stove group:** n=18 participants, provided with one single-burner Sonifer infrared stove each (3.5kW, \$52). The infrared stoves had knob control temperature adjustment and were made from metal with a glass top.
4. **Control group:** n=19 participants, not provided with any eCooking appliances.
5. **Businesses group:** n=4 participants, Provided with 2 quantities of stoves based on their preference.



Figure 3: Project stoves in use consisting of: (a) EPC; (b) Induction stove; (c) Infrared stove.

For the business cohort, a broader mapping exercise was first conducted, surveying 13 enterprises to understand their typologies and cooking patterns. From this pool, four businesses were strategically selected to ensure diversity in cooking scale and menu complexity. Each business was then assigned two of the three stoves (EPC, induction, or infrared) depending on their cooking needs.

3.3 Data collection tools and procedures

A suite of complementary data collection tools was deployed across the study timeline to capture quantitative and qualitative insights. Figure 4 shows a flowchart of the data collection process. The process commenced with a detailed baseline survey administered to all selected households and businesses. This instrument gathered data on demographics, asset ownership, detailed cooking habits, fuel expenditure, health perceptions related to smoke exposure, and any prior experience with eCooking technologies.

The primary instrument for capturing granular behavioural data was the cooking diary, adapted from methodologies developed under the Modern Energy Cooking Services (MECS) programme [22]. Participants were tasked with recording every cooking event over one-week periods in each phase. They captured the type of dish prepared, the stove(s) used, the quantity of each fuel consumed per day (requiring fuel weighing), and the cooking duration. This yielded high-frequency data on fuel consumption, fuel stacking, purchasing patterns and culinary practices.

The cooking diaries were supplemented with additional surveys. At the end of Phase 2, a usage survey was administered that drew upon the Clean Cooking Alliance's Stacking Toolkit [23] to capture quantitative data on patterns of use for the eCooking appliances. This included questions about the drivers of fuel stacking, user satisfaction, perceived changes in fuel use, and challenges encountered. An additional exit survey was administered at the end of Phase 3 to capture further insights on the experience of cooking with free electricity.

The surveys were accompanied by a series of Focus Group Discussions (FGDs) that segregated participants by appliance type. There were three FGDs for households (each focused on a different appliance with n=9 participants in each), and one with the businesses. These discussions provided rich qualitative data on social perceptions, shared experiences, nuanced barriers to adoption, and unintended consequences not easily captured through surveys.

Lastly, the study drew upon quantitative measurements of electricity use at both the stove and household level. HumEn use smart meters from Sparkmeter to provide remote real-time monitoring of consumption patterns at the household level. In addition to this, eCooking appliance usage was monitored throughout the project via a second appliance-level smart meter.

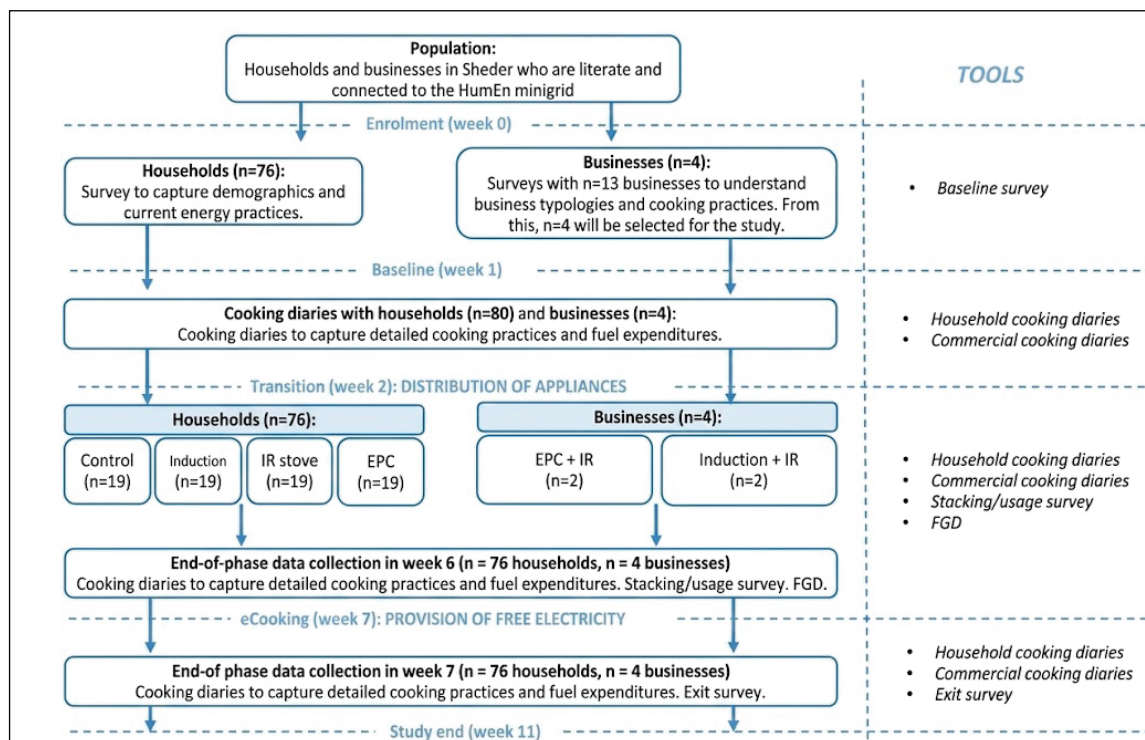


Figure 4: TABLE study structure.

Field implementation was managed by a team of four enumerators from Addis and eight enumerators from Sheder. The local enumerators were critical for community engagement, translating research tools to the local language (Somali), and cultural mediation. A coordinated field structure was implemented wherein each national enumerator supervised two local enumerators. All procedures adhered to predefined Standard Operating Procedures, with rigorous attention to securing informed consent and maintaining ethical standards throughout the research engagement.

Stove training was conducted after the completion of baseline cooking diary and fuel stacking data collection. Participants in the treatment group were organized according to the three stove types—Induction, Electric Pressure Cooker (EPC), and Infrared—to ensure targeted and effective training. Training manuals covering stove operation, safe use, and selected local recipes were developed, translated into Somali, and distributed to all participants. Practical stove demonstrations were held at the HumEn Solar Mini-Grid compound over approximately three hours and facilitated by Somali-speaking trainers. Households were grouped by stove type to allow focused demonstrations, followed by question-and-answer sessions. Business users received individualized training sessions tailored to their specific operational needs. Participants practiced preparing common local dishes, including rice, beans, spaghetti, tea, etc... with emphasis on safety, efficient energy use, and troubleshooting common challenges.

During the cooking diaries data collection, local enumerators were responsible for the daily visit to their assigned households, which involved collecting the previous day's diary (completed by the household), checking entries for completeness, weighing remaining fuel, providing corrective guidance, and conducting informal interviews to capture contextual observations. All paper-based data were subsequently digitised by enumerators using the CommCare mobile data platform, which facilitated real-time data quality checks and centralised storage.

All three surveys were administered directly through CommCare and performed jointly by the Addis and Sheder enumerators. The FGDs were held in Somali and primarily facilitated by the local enumerators, with data captured via both dedicated note-takers and recordings.

Participants did not receive any direct incentives for their participation. However, at the end of the study they were provided with the opportunity to purchase the stove at an 80% discount.

3.4. Data analysis

Data analysis employed a convergent mixed-methods approach. Quantitative and qualitative datasets were analysed separately before integration to provide a comprehensive interpretation. Quantitative data from the baseline survey, cooking diaries, metered data, and stacking surveys were cleaned, coded, and analysed using a combination of Python and Excel. The raw stove meter data consisted of voltage and current measurements at 30-second intervals. This was transformed to 30-second consumption estimates (kWh) and subsequently to a set of cooking events¹. The events formed the main unit of analysis.

1. A cooking event was defined as a window of continuous appliance usage. Events using less than 0.01 kWh of energy were discarded and events were grouped together if they were less than three minutes apart.

Basic descriptive statistics were generated to summarise demographic profiles, fuel consumption averages, perceptions of eCook stoves, and electricity usage patterns across phases and participant groups. This analysis aimed to quantify patterns in traditional fuel displacement and describe the consumption profiles and behaviours associated with each appliance type.

Qualitative data from FGDs and open-ended survey responses were transcribed, translated, and subjected to thematic analysis. This process involved iterative coding to identify recurring patterns, themes, and narratives related to user experiences, adoption barriers, perceived benefits, and cultural acceptability. The qualitative findings provided essential context for interpreting the quantitative results, helping to explain the observed behavioural trends and consumption patterns. Finally, through methodological triangulation, insights from both quantitative and qualitative strands were synthesised. This integration allowed for a more nuanced understanding of the complex interplay between technical performance, cost, user behaviour, and social norms in determining the viability of eCooking solutions in a humanitarian setting.

3.5 Strengths and Weaknesses

This study has many points of novelty. To our knowledge, it is the largest cooking diaries study conducted to date; the first interventional study directly comparing the uptake and use of EPCs, induction stove and infrared stoves; one of the first studies on market-based clean cooking interventions in humanitarian settings; and the first study collecting in-depth data on the Sheder community's cooking practices.

The study's particular strengths lie in its large sample size, its aggregation of multiple sources and types of data (ranging from highly objective metered stove and household electricity use data to qualitative focus group discussions) and its three-phase approach which provided an understanding of how affordability constraints shaped eCooking practices.

It is also important to acknowledge its limitations. Logistical constraints significantly shaped the study's timeline. Fieldwork was limited to 44 days over two field visits, necessitating a condensation of the planned phases, and is shorter than ideal for an interventional study. Yet, relatively stable recorded cooking patterns throughout this time suggest the duration was still sufficient.

Participant fatigue emerged as a concern towards the end of Phase 2 due to the repetitive nature of maintaining detailed daily cooking diaries over an extended period. This was combated by significantly cutting the length of the endline survey. The household cooking diaries from Phase 3

still exhibited high levels of completion suggesting high data reliability. Fuel weights and purchases were not consistently recorded in the business cooking diaries, which meant the research team were unable to calculate the cost of cooking for this group of participants or changes in fuel procurement time.

The research tools required constant minor adjustments in the field to better fit the literacy levels and daily routines of participants, highlighting a tension between methodological rigour and contextual practicality. The study's deep reliance on local enumerators was essential for access and communication but also introduced a layer of interpretation and potential bias in data collection and translation.

4. Results

This section of the report presents the study results according to the different research methods. Table 2 provides an overview of the data collected.

Table 2: Summary of data collected by phase.

		Phase 1	Phase 2	Phase 3
Baseline surveys	Households	n=76 participants	-	-
	Businesses	n=13 participants	-	-
Usage survey ²	Households	-	n=52 participants	-
	Businesses	-	n=4 participants	-
Exit survey	Households	-	-	n=52 participants
	Businesses	-	-	n=4 participants
Minigrid metered data	Households	23 days of data, n=76 participants	33 days of data, n=76 participants	16 days of data, n=76 participants
	Businesses	23 days of data, n=4 participants	33 days of data, n=4 participants	16 days of data, n=4 participants
Stove metered data ³	Households	-	33 days of data, n=53 participants	16 days of data, n=53 participants
	Businesses	-	33 days of data, n=4 participants	16 days of data, n=4 participants
Cooking diaries	Households	7 days of data, n=76 participants	7 days of data, n=76 participants	7 days of data, n=76 participants
	Businesses	7 days of data, n=4 participants	7 days of data, n=4 participants	7 days of data, n=4 participants
FGDs	Households	-	3 groups, n=8 participants each	-
	Businesses	-	1 group, n=8 participants	-

4.1 Surveys

4.1.1 Baseline Survey

4.1.1.1 Households

The surveys were targeted at the main cook in the households. They were almost all female (95%), with 87% being the mothers of the heads of the households, revealing high prevalence of multigenerational families. This was further demonstrated by large household sizes, with a mean household size of either and roughly three-quarters of the households having more than seven members. Mothers (67%) and daughters (33%) tended to be the main cooks, with mothers being responsible for making cooking fuel decisions in most cases (88%).

2. The usage and exit surveys did not include the household control group.

3. Note there was no stove metered data available during phase 1 (baseline) or for the control group participants.

All households depended on humanitarian aid as a source of income with four-fifths (83%) also frequently deriving money from other sources. These were most commonly from small businesses (38%), daily casual labour (26%), cleaning services (17%) and remittances (9%). Participants mostly reported earning 6,000 to 10,000 birrs per month (55%), with rest earning 11,000 birr and above (26%) or less than 5,000 birr (18%).

Ninety-seven per-cent (97%) of the participants reported using the minigrid as a source of energy (Figure 5). Just one (1%) reported having an off-grid solar system whilst six (8%) owned solar lighting products. Other sources of electricity included rechargeable batteries (n=1, 1%) and dry cell batteries (n=6, 8%).

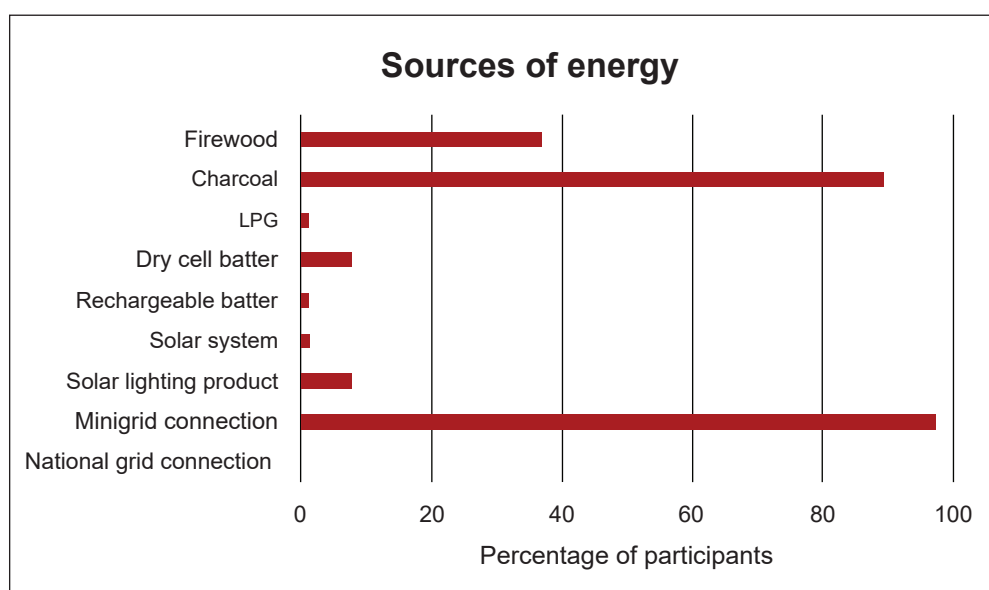


Figure 5: Sources of household energy.

The median minigrid token purchase size was 200 birr, with over 70% of the participants commonly purchasing electricity tokens of between 100-200 birr. Tokens were evenly split between being purchased bi-weekly (29%), weekly (29%) and monthly (27%), with some also purchasing every three weeks (14%). In terms of minigrid performance, over 70% of the participants reported facing 1-2 outages in a week, while 22% face none. Outages most often occurred in the evenings (reported by 56% of all participants) with a third of participants experiencing 7-12 hours of no electricity per week, when they fail to charge their token on time. The minigrid operator's internal data shows high service levels to the camp, implying that reported gaps of electricity access were fully due to inability to pay for tokens rather than unavailability of power.

Charcoal was the primary cooking fuel for 87% of households, with a small number primarily using firewood (12%) and one mainly using electricity (1%). Households usually used just one cooking fuel, with the most common combination of fuels being charcoal and firewood (22%, Figure 6). The most widespread stoves were the BURN jikokoa (owned by 74% of households), the giregire (18%) and three stone cooking fires (9%). Twenty-six per-cent (26%) possessed

electrical cooking appliances, mostly blenders or juicers (17%) or kettles (5%). Those who cooked with charcoal usually did so inside a dedicated kitchen in the main dwelling (42%) or in a separate building (39%), whereas firewood was most often used outside (17%) or in a separate building (16%). Just 5% cooked with firewood inside the main dwelling.

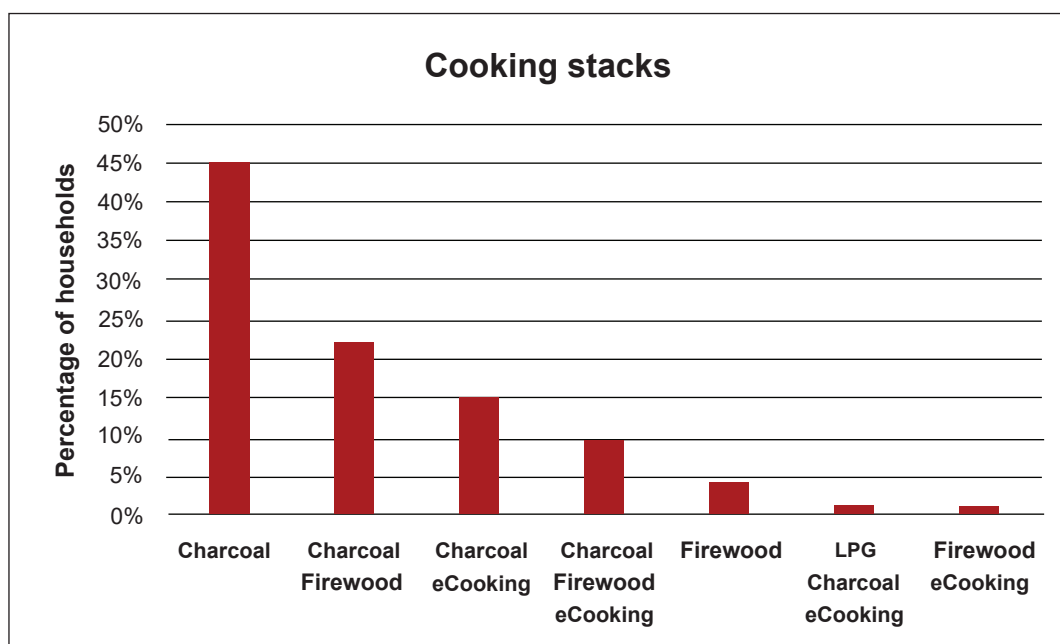


Figure 6: Combinations of fuels ("stacks") for households at baseline.

Charcoal was usually purchased weekly (35%) or monthly (32%), with only a handful of houses making daily purchases (7%). It tended to be bought in medium (60%) or large (16%) sacks at a cost of 1000-1200 birr (45%), or 700-900 birr (27%).

Firewood was most often gathered for free (21% of all participants) with fewer purchasing it (14%). Those who purchased it tended to do so weekly (15%) or daily (4%) and by donkey load at a price ranging from 300-800 birr. Those who collect firewood for free tend to do so weekly (14%) or daily (4%) with an average collection time of 2 hours.

Four-fifths (78%) of participants had accounts in formal bank institutions, with nearly 50% having accounts in the Commercial Bank of Ethiopia and nearly 60% in Kaafi Microfinance. A quarter (25%) had access to informal finance institutions and three-quarters (74%) access to rotational group savings. The vast majority (78%) reported being able to access loans and credits from shops and 43% from relatives, friends, and acquaintances. All had access to mobile money accounts, specifically Ebirr. Some participants also had accounts in HelloCash (13%), ZAAD (11% - mobile money service from Somaliland) and Sahay (5%).

Figure 7 below show participant perceptions of air quality and thermal comfort when cooking and not cooking. Air quality was perceived to degrade significantly for over 90% of the participants to 'poor' or 'very poor' when cooking. Similarly, thermal comfort was reported to improve for over 50% of the participants when not cooking.

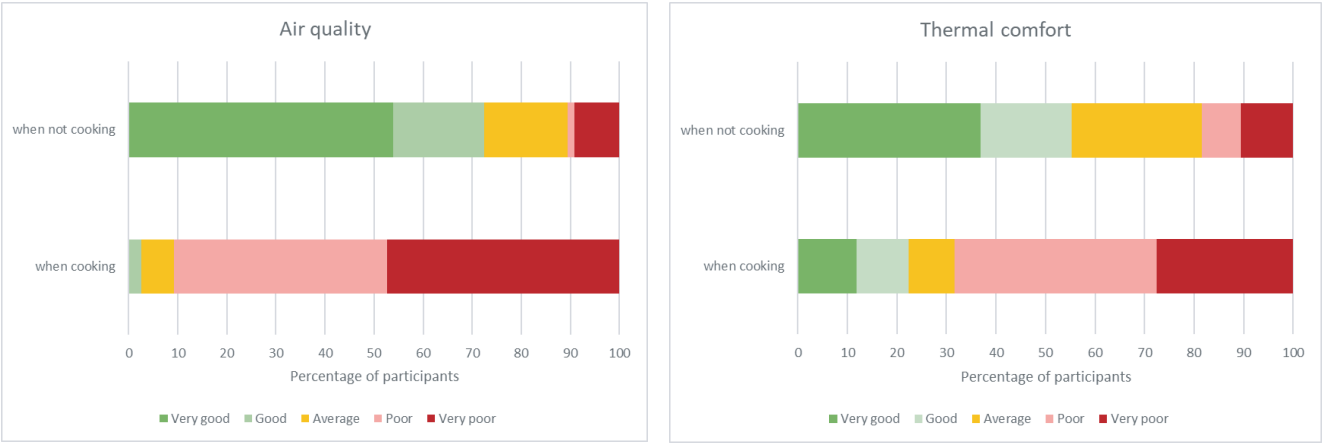


Figure 7: Household main cooks' perceptions of air quality and thermal comfort at baseline.

The main cooks have reported various physical ailments, with headaches (20%), eye irritation (31%), shortness of breath (16%), and coughing (16%) reported multiple times a day (Figure 8).

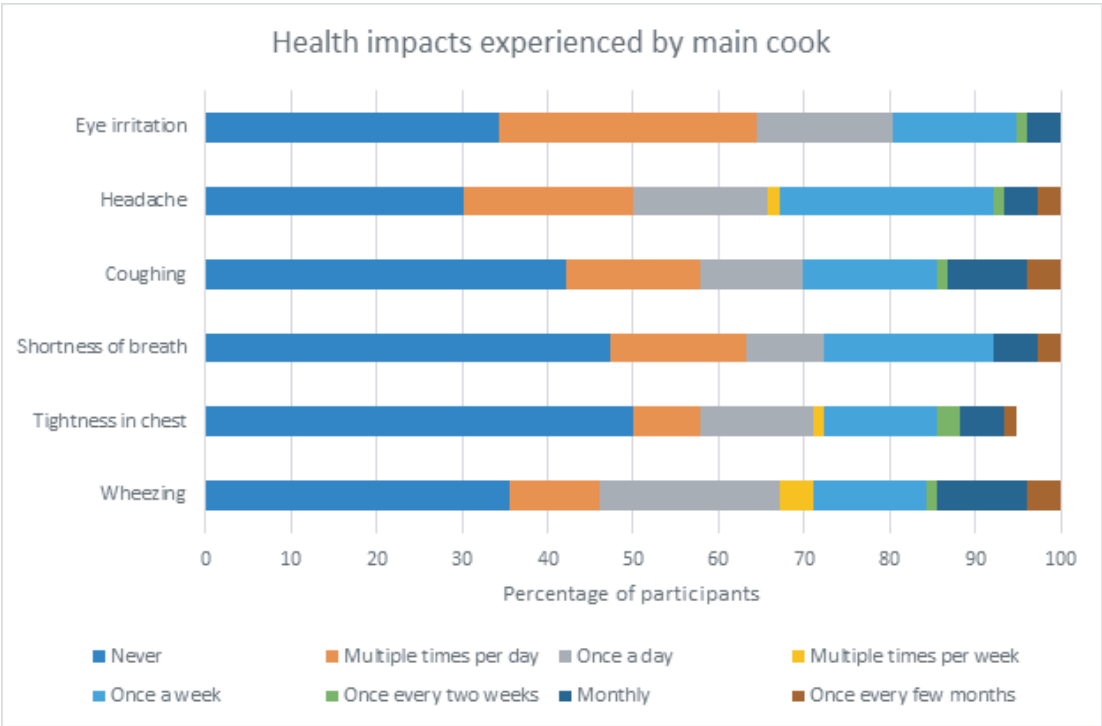


Figure 8: Self-reported health impacts experienced by household main cook at baseline.

Finally, Table 3 compares key characteristics across the four study groups. It shows similar household sizes, median incomes, and proportion cooking with charcoal across all four groups. Differences emerged in the proportion cooking with electric appliances at baseline (ranging from 13-41%) and median electricity spend (270-450 birr/month), revealing variations in baseline energy consumption practices. Overall, these results suggest that the cross-group comparison presented in this analysis is justified but imperfect, suggesting that some observed differences may be attributed to participant variation rather than the intervention.

Table 3: Comparison of baseline characteristics of household groups.

	Number participants	Median HH size	Median HH income category	Proportion using charcoal as primary cooking fuel	Proportion with electric cooking appliances	Median monthly electricity spend (birr)
Control	20	8	6,000-10,000	83%	13%	300
EPC	18	8	6,000-10,000	83%	28%	450
Induction	17	8	6,000-10,000	88%	41%	270
Infrared	18	8	6,000-10,000	94%	28%	300

4.1.1.2 Businesses

All 13 businesses surveyed were restaurants with eat-in and take-away services, with three also offering delivery services. All of them operate every day of the week, except one, which is closed on Fridays. Over half of the businesses had been in operation for 1 to 5 years, while 15% had each been open for 10-15 years, over 15 years, and under 1 year respectively.

The number of cooks ranged from one to seven, with the majority (n=7) having two cooks. The cooks were mostly women; only one business had solely male cooks.

The most popular food items were pasta (served by 100% of the restaurants) and rice (77%). Other common foods served included meat (38%) and ful (38%). Consequently, boiling and steaming are the most common cooking processes for the most popular dishes. The number of customers served per day ranged from 12 to 114, with an average of 40. Ten of the businesses (77%) had an average monthly income of 11,000 birr or above, while the remaining earned between 6,000 and 10,000 birr. Quieter trading days were Fridays (54%) and food distribution days (23%). This is because Sheder camp residents are occupied in the Friday religious and festivity practices, and/or queuing for ration.

As with households, the most commonly used fuel in the businesses was charcoal (used by 92% of businesses, or all but one) followed by firewood (46%) and electricity (31%). The most prevalent stacks of fuels were solely charcoal (46%), charcoal and firewood (23%) and charcoal, electricity and firewood (15%, Figure 9). The 12 charcoal-using businesses tended to use improved charcoal stoves in the main dwelling, whereas of the five businesses that used firewood, three did so in three stone fires stoves and two in improved firewood stoves, in a mixture of outdoor and indoor locations.

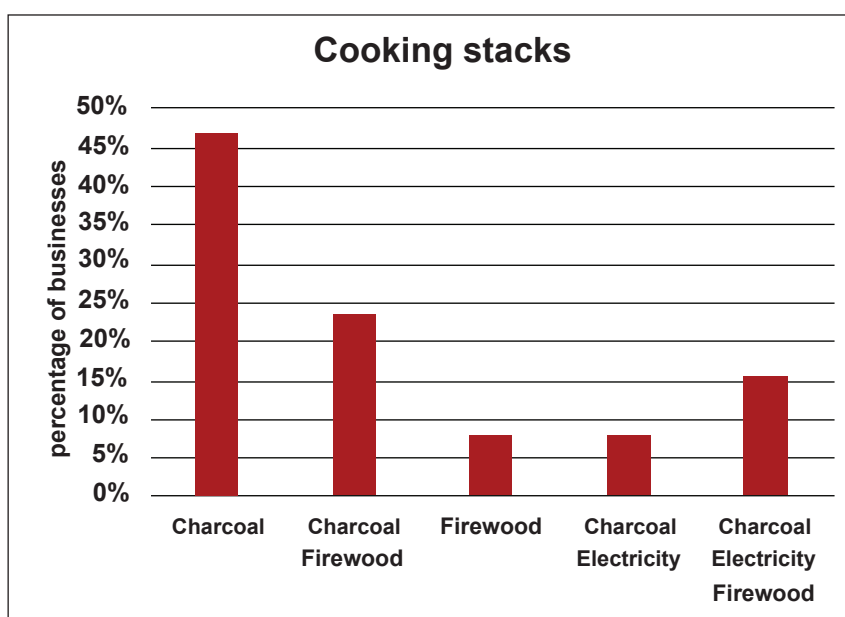


Figure 9: Business cooking stacks.

Charcoal purchases were similar to those of households, with most businesses (77%) purchasing charcoal on a weekly basis, and all purchasing medium sacks, usually at a price of 1,000 to 1,500 birr. Firewood was always purchased and tended to be done so weekly by the donkey or load, with prices ranging from 500 to 1,500 birr each time.

Two-thirds (69%) of businesses had accounts with formal financial institutions, especially with the Commercial Bank of Ethiopia (54%), and 62% had access to rotational group savings. Most (69%) had no access to loans or credit, with those that did (31%) relying on shops, NGOs and bigger business firms as lines of credit. They all had a mobile money account with Ebirr with only one business reporting accounts with other providers.

Almost all (92%) of businesses reported 'good' air quality when not cooking, which significantly changed when cooking, with 85% reporting 'poor' or 'very poor'. Conversely, thermal comfort was reported to improve for 77% of businesses when cooking, likely because the survey was conducted during colder seasons and this was the only form of heating available to the businesses (Figure 10).

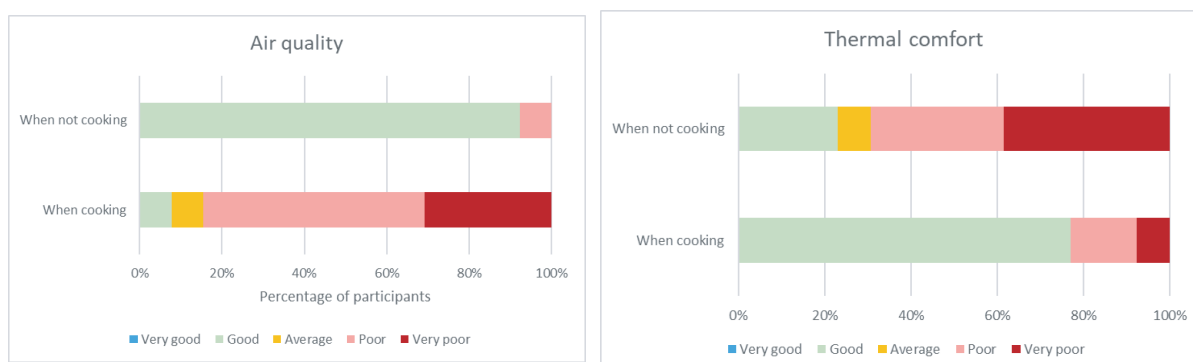


Figure 10: Business main cooks' perceptions of air quality and thermal comfort at baseline.

Due to the intensity of the cooking activities, the main cooks reported various physical ailments, with eye irritation, headaches, coughing, and shortness of breath occurring multiple times a day reported by half of businesses for each (Figure 11).

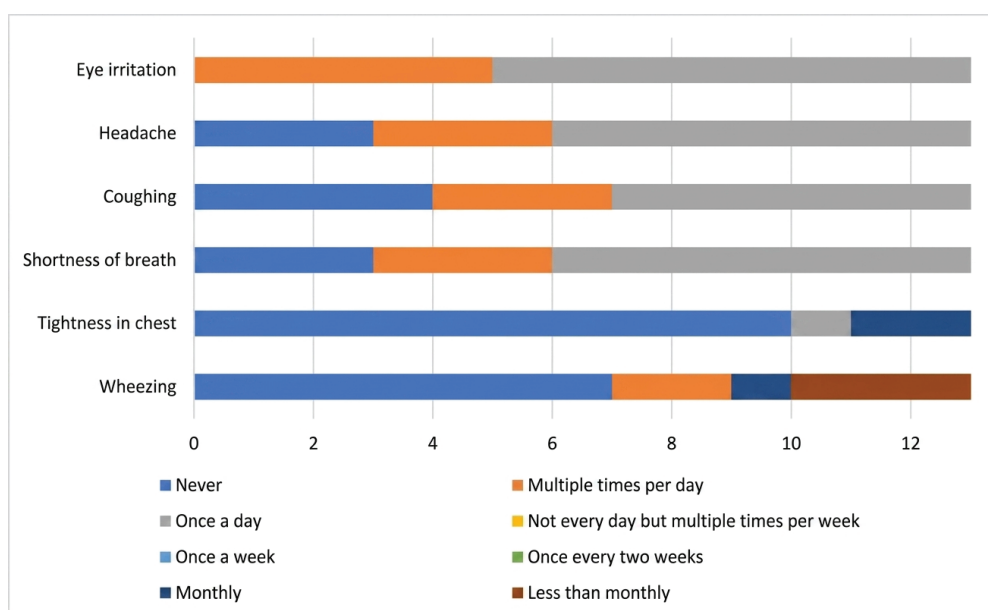


Figure 11: Self-reported health impacts experienced by business main cook at baseline.

4.1.2 Usage Survey

The usage survey was conducted at the end of Phase 2, after participants had spent roughly one month using their appliances. It was only conducted with those who received an eCooking appliance (i.e. the control group was excluded) and examined to the period where fuel was purchased at the normal tariff rate rather than provided for free.

4.1.2.1 Affordability

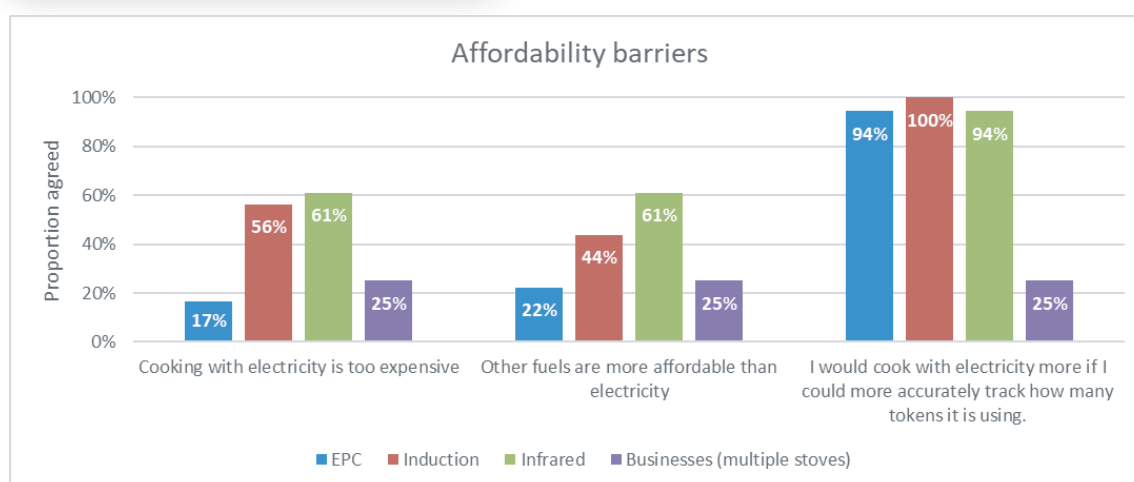


Figure 12: Affordability barriers to eCooking at the end of Phase 2.

The businesses experienced fewer affordability barriers than the households, although this could be a quirk due to the small sample size (n=4 for businesses versus 16-18 for the household groups). EPC users found electricity significantly more affordable than other groups, with infrared being perceived as slightly more expensive than induction (Figure 12). These observations mirror the efficiencies of the appliances. Almost all of the household participants said they would cook more with electricity if they could better track electricity consumption.

Four-fifths of participants self-reported that their total electricity cost increased or significantly increased for 80% of due to the introduction of the eCooking appliances.

4.1.2.2 Cultural factors

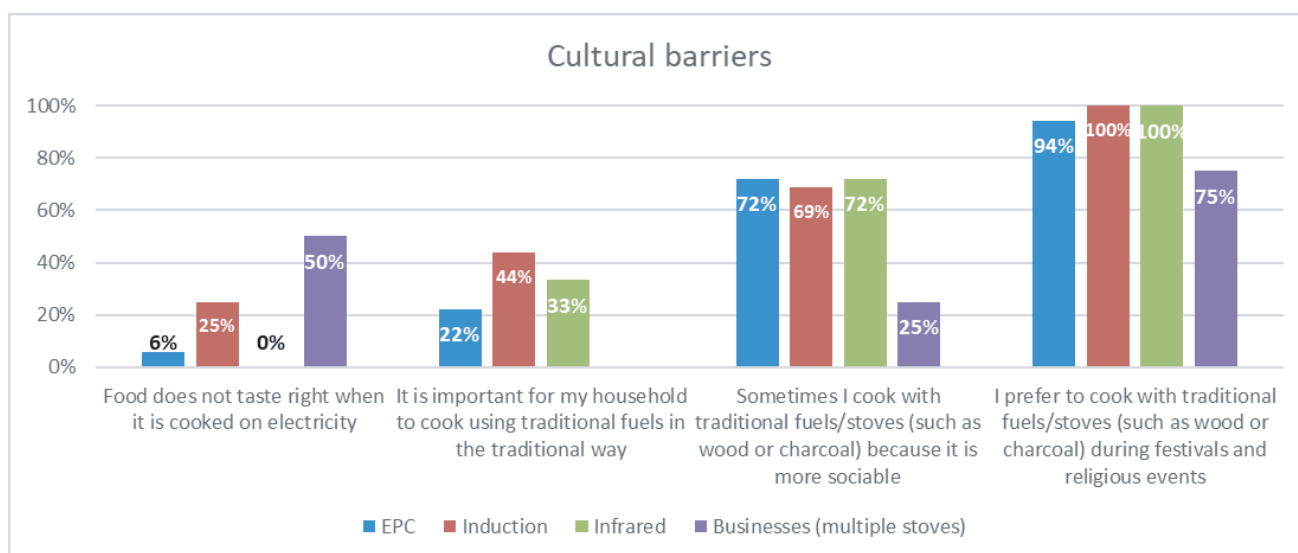


Figure 13: Cultural barriers to eCooking at the end of Phase 2.

Household participants liked the taste of food cooked with electricity, especially those with EPCs and infrared stoves. Half of the businesses, however, believed that food did not taste right when cooked on electricity. There was relatively low attachment to using traditional fuels in the traditional way, particularly for the EPC users. However, three-quarters of participants said that they sometimes cooked with wood or charcoal because it was more sociable, and all of them preferred to use traditional fuels during festivals and religious events. This could be due to the size of the pots and EPCs, as larger quantities of food tend to be cooked during these times.

4.1.2.3 Alternative end-uses of stoves

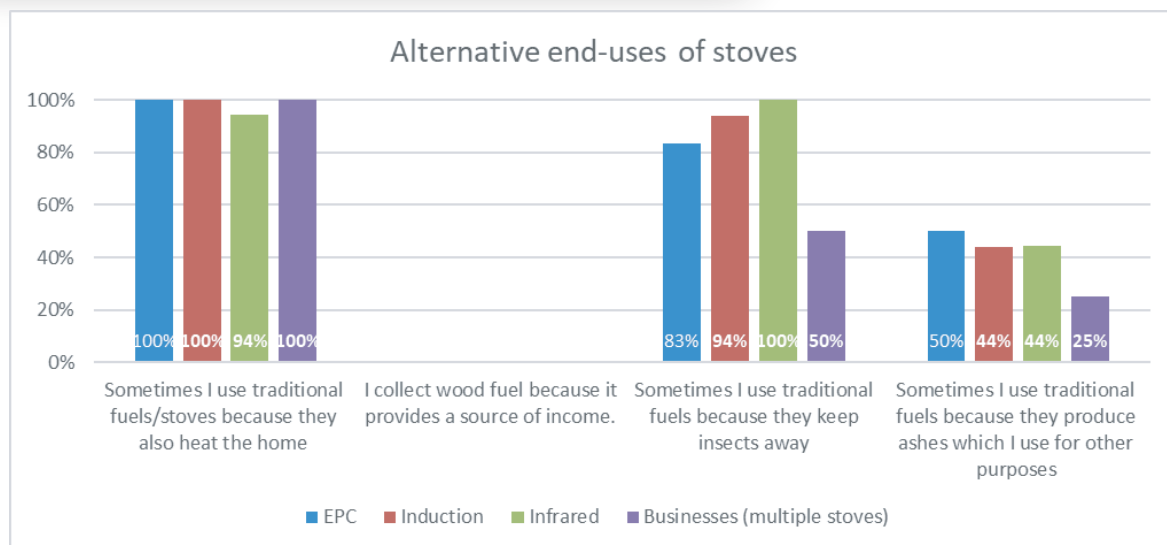


Figure 14: Alternative end-use barriers to eCooking at the end of Phase 2.

The survey revealed several common alternative end-uses of traditional stoves that continued to drive their use. Almost all households and businesses used woodfuels to keep insects away and heat their homes. The latter was an unsurprising finding given that the survey was conducted in the cold season. Around half of households also used ashes produced by burning wood for other purposes, to repel insects. Businesses also ubiquitously used woodfuel for heating, but only half did so to keep insects away and a quarter to produce ashes. No households or businesses collected wood fuel to provide a source of income.

4.1.2.4 Equipment Compatibility

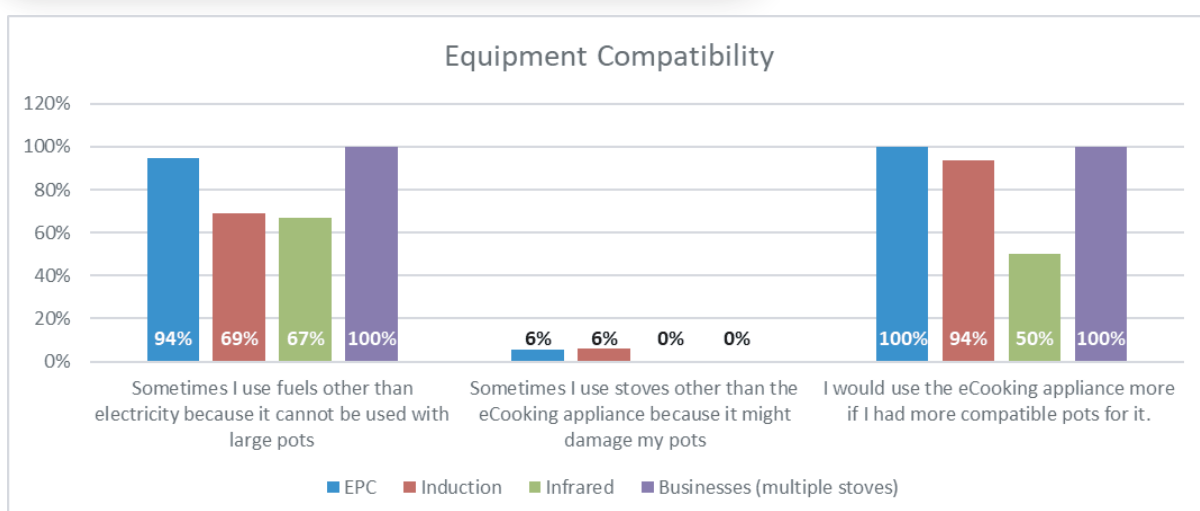


Figure 15: Equipment compatibility barriers to eCooking at the end of Phase 2.

Almost all (94%) of EPC users (which included all four businesses) were limited by the pot size (6-8L). This was also the case for roughly two-thirds of the household induction and infrared stove users. This was a surprising finding for the infrared users, who were able to use their already-existing pots on the stove. This could reflect limitations with the size of the burner, which would likely result in poor heat distribution if paired with a much larger pot. EPC and induction users also almost all (100% and 94% respectively) said they would use their appliance more if they had more compatible pots for it, whereas this was true for only 50% of infrared stove users. This finding can be explained by the infrared stove being the only appliance compatible with households' already-existing cookware. There were low levels of concern about the eCooking appliances damaging existing pots.

4.1.2.5 Functionality

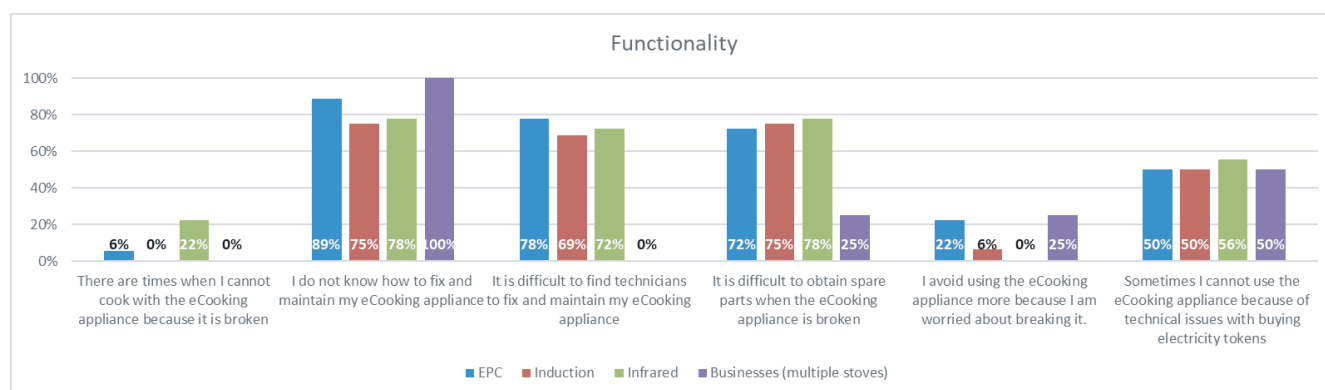


Figure 16: Functionality barriers to eCooking at the end of Phase 2.

Very few participants experienced stove breakages during the first month of use. Only three respondents (5%) said they were unable to cook for a day due to technical or maintenance issues. However, the survey revealed low levels of knowledge about what to do if the appliance was broken, with over three-quarters of participants being unsure how to fix the stoves, how to find technicians to help them if needed and how to procure spare parts. This reflects that the intervention was a pilot without for procedures for maintenance and customer service in place. Few participants limited their stove use due to fears about breaking it, but half reported encountering technical issues with purchasing tokens that prevented them from using the stove.

4.1.2.6 Household Dynamics

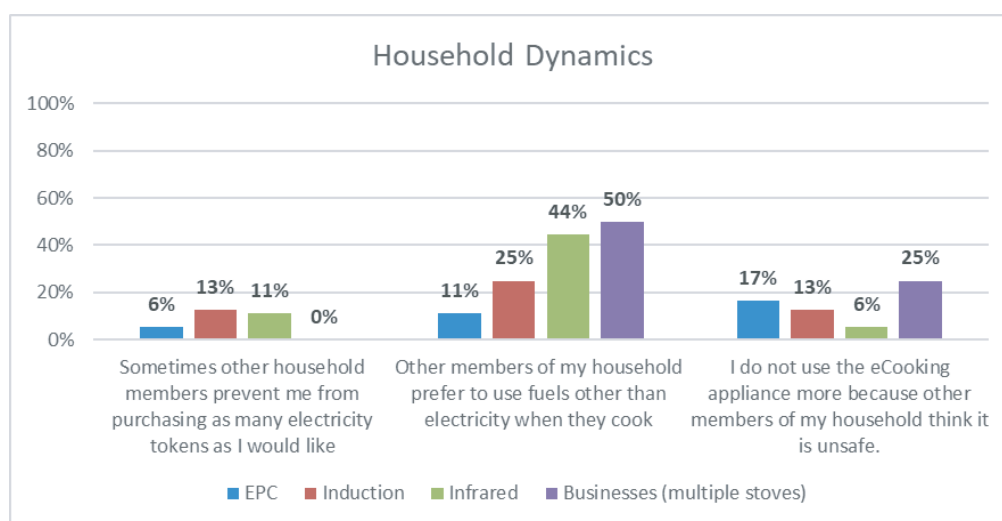


Figure 17: Household dynamics barriers to eCooking at the end of Phase 2.

Other household members seemed to have little influence over the stove and fuel used by the main cook. Overall, just 9% of participants said that other household members prevented them from purchasing as many tokens as they would like and 13% that their use was limited by others' perceptions on unsafety. However, around a third of total participants said that other household members preferred to use fuels other than electricity when they cooked, with this being most prominent amongst infrared stove users (44%). This demonstrates the importance of delivering training interventions to the whole households rather than just the main cook.

4.1.2.7 Knowledge and Safety

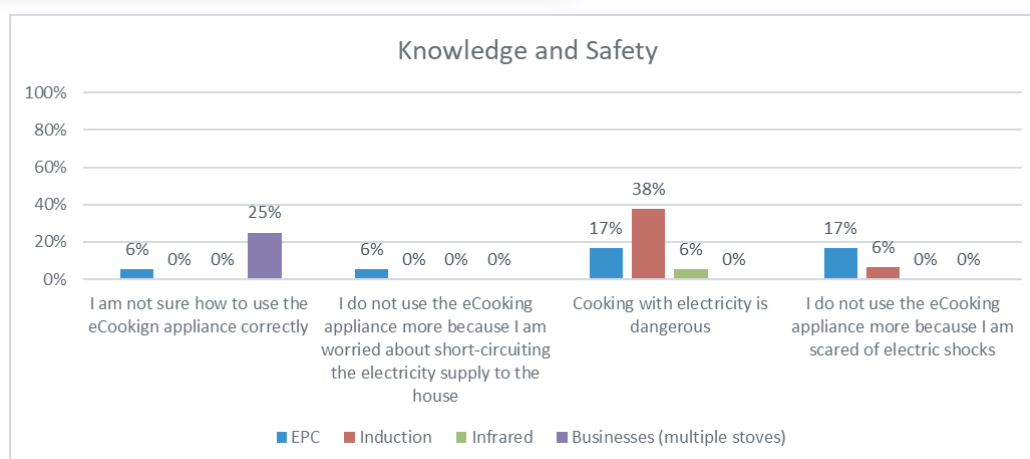


Figure 18: Knowledge and safety barriers to eCooking at the end of Phase 2.

There were few knowledge barriers or safety concerns amongst the main cooks. However, induction stove recipients perceived electricity as being significantly more dangerous than the other groups (38%); a surprising find as EPCs generally bear larger safety concerns. This could point towards the need for more or amended training for all participants.

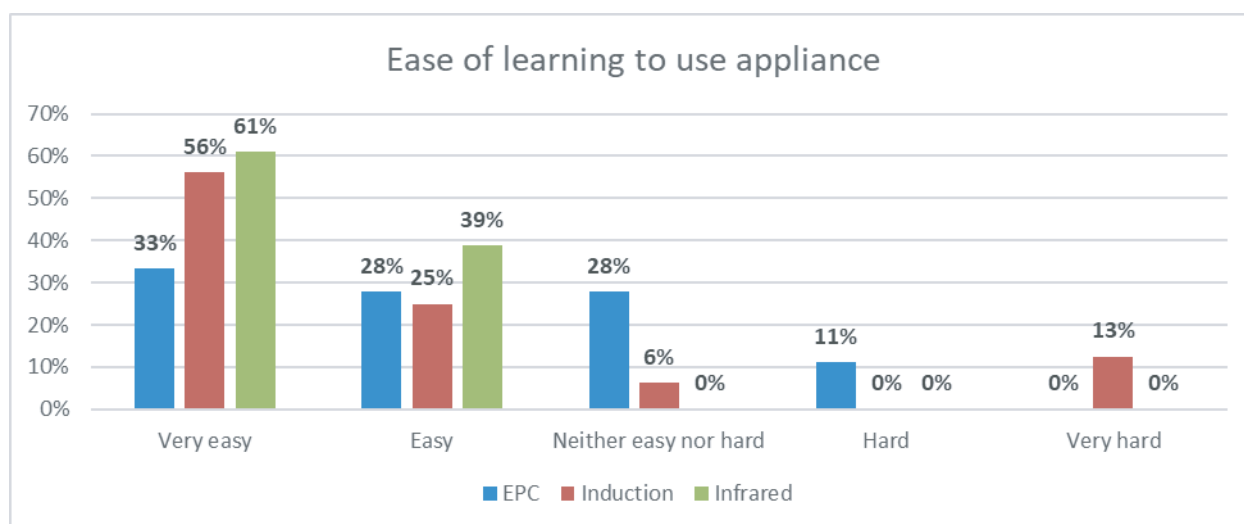


Figure 19: Self-reported ease of learning to use eCooking appliances at the end of Phase 2.

Over 80% of the participants found it “very easy” or “easy” to learn how to operate the appliances, whereas just 7% found it “hard” or “very hard”. Participants found it simplest to learn to use the infrared stove (61% “very easy” and 39% “easy”) and hardest to use the EPC (33% “very easy” and 28% “easy”). Due to the initial low familiarity with the appliances, over 85% of the participants feel that training would be essential for eCooking scale-up in Sheder.

4.1.2.8 Supply

Overall 18% of users said there were times where they could not use the eCooking appliance due to insufficient electricity supply, which was evenly split across the three stove types. It is unclear whether this was due to power supply issues from the minigrid or running out of tokens. Almost all (93%) did not feel that the introduction of the eCooking appliances significantly affected the quality of the electricity supply. Nine participants (16%) said there were days where they could not use the eCooking appliances due to electricity supply constraints, losing an average of two days of cooking opportunity each.

4.1.2.9 Technical Issues

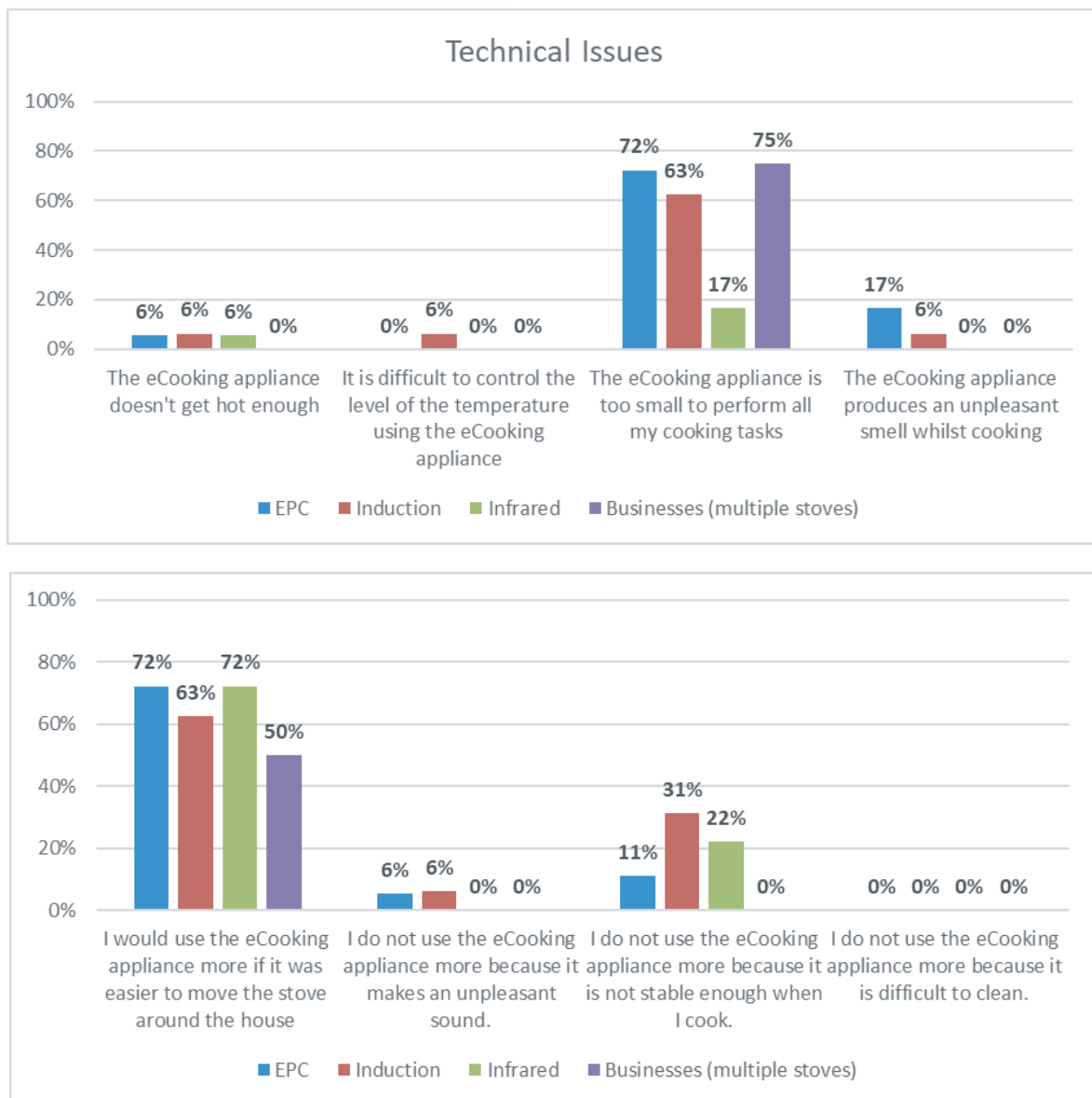


Figure 20: Technical issues-related barriers to eCooking at the end of Phase 2.

Participants were happy with the temperature reach and control of the stoves, their sound and smell, and considered them easy to clean. The EPC and induction stoves were widely considered to be too small, whereas this was only an issue for 17% of infrared stove users (who could use their already-existing cookware with the stove), pointing to an issue with the size of the provided pots and pans for the EPCs and the induction groups rather than the stoves themselves. Most household participants said they would use the stoves more if they were easier to move around the home; however, this was less of an issue for the businesses, where cooks tend to be confined to a dedicated cooking area. A third of induction users reported that instability issues led to stacking. This could be due to this appliance having a slippery glass surface.

4.1.2.10 Time Aspects

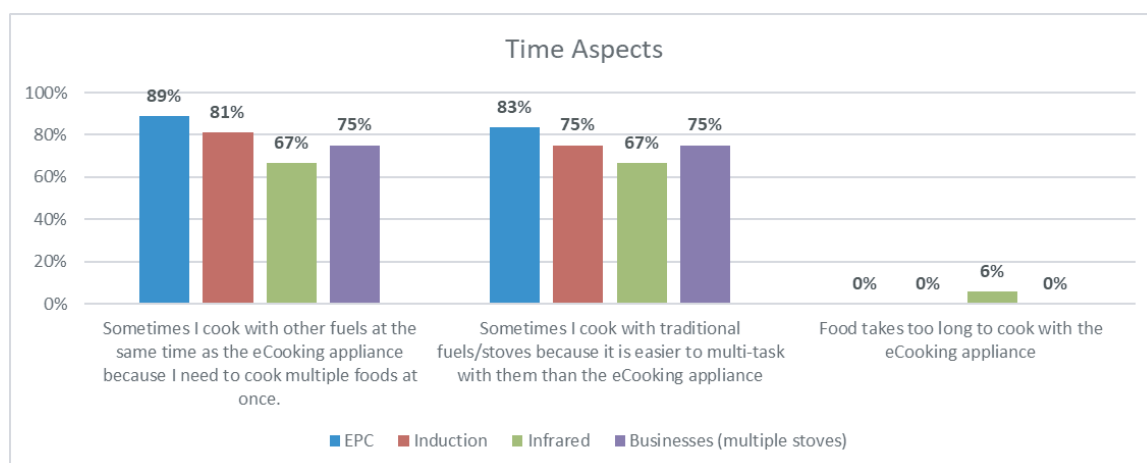


Figure 21: Time aspects barriers to eCooking at the end of Phase 2.

There was widespread satisfaction with the speed of preparing dishes on the eCooking appliances. Stacking with traditional fuels occurred for four-fifths of participants due to the need to cook multiple foods at once; unsurprising given that each of these stoves only had one burner. Participants also found it easier to multitask when using traditional fuels, potentially due to their slower cooking rate requiring less supervision.

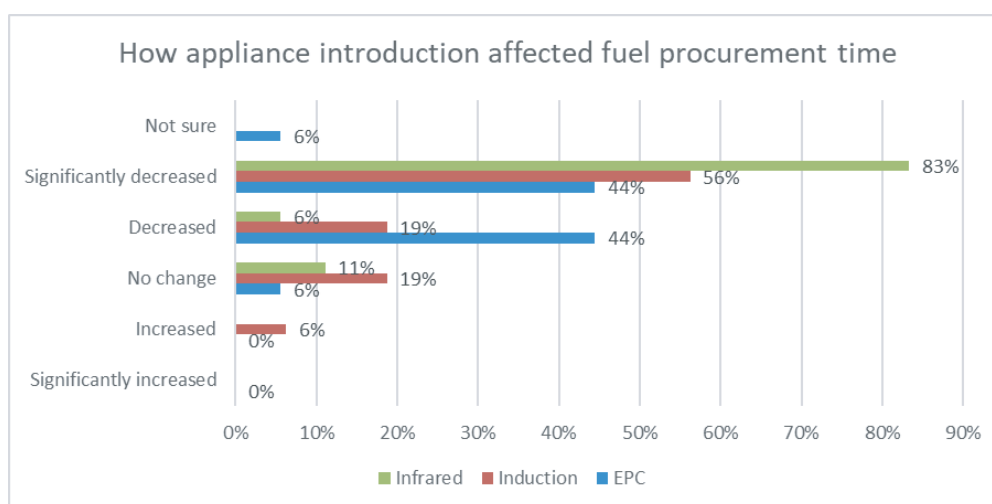


Figure 22: Self-reported impacts of appliance introduction on fuel procurement time.

The introduction of eCooking appliances decreased fuel procurement time for most (78%) of participants overall. The impact was largest for the infrared stove, with 83% of recipients reporting significant decreases in time spent fetching fuel. Interestingly, fuel procurement time increased for some of the participants in the induction stove treatment group (6%). The reasons for this are unclear.

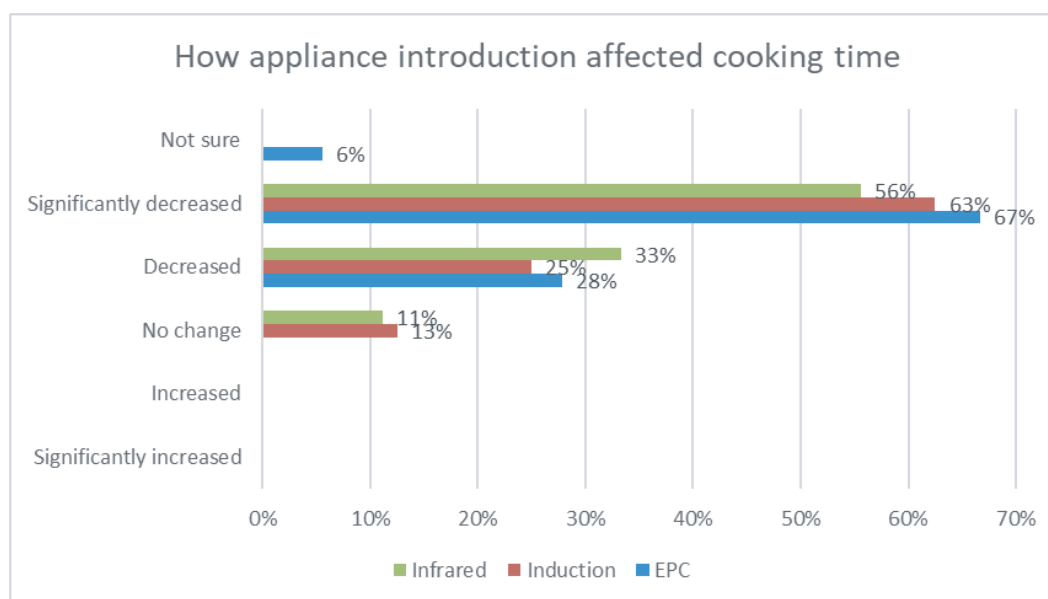


Figure 23: Self-reported impacts of appliance introduction on cooking time.

Similarly, the eCooking appliances significantly decreased cooking time for 84% of participants overall. It significantly decreased for more than half of the EPC treatment group (67%), as it did for the induction stove group (63%) and IR stove group (56%). A small percentage of participants across reported no changes in cooking times for the induction stove and IR stove groups (13% and 11%, respectively).

The time saved on fuel procurement and/or cooking was repurposed to other social and domestic activities like spending time with family (reported by 68% of participants), caregiving (52%), completing other household chores (48%), cooking more food (45%) and enjoying extra leisure time (45%). It less often went to “productive” purposes such as business activities (36%), caring for livestock or poultry (34%) or learning new skills (7%).

4.1.2.11 Compatibility with cooking processes and foods

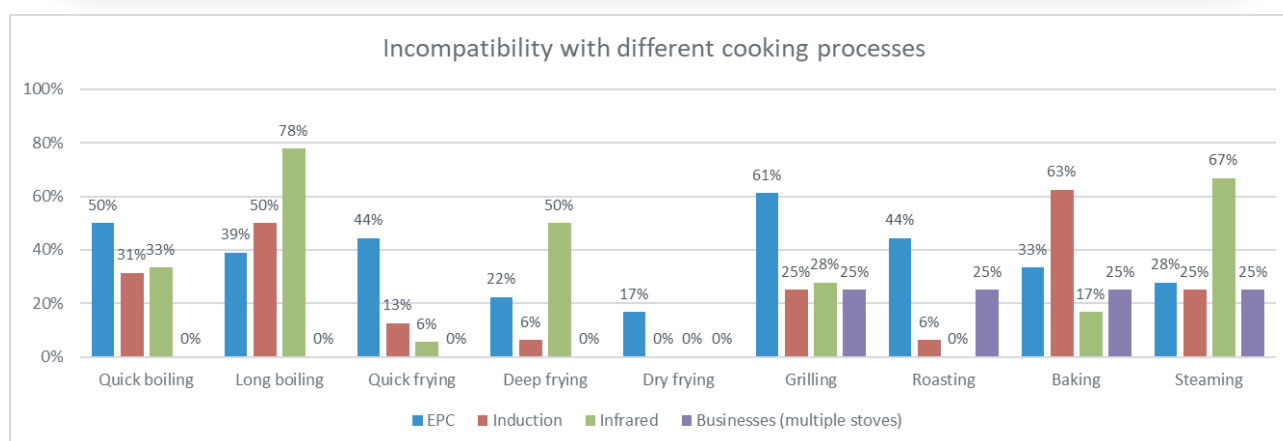


Figure 24: Incompatibility of eCooking appliances with cooking processes.

Figure 25 shows how compatibility with different cooking processes varied by appliance. The EPC was perceived as being least compatible with grilling (stated by 61% of participants), quick boiling (50%), roasting (44%) and quick frying (44%). It was best suited to dry frying and deep frying. These results are unexpected as EPCs are specifically designed to boil foods in an accelerated fashion.

The induction stove was least compatible with baking (63%), long boiling (50%) and quick boiling (31%). It was best suited to frying and roasting. The infrared stove was particularly incompatible with long boiling (78%), which probably is due to its high running costs. It was best suited to dry frying, quick frying and roast, although interestingly not deep frying. These results broadly reflect the induction and infrared stoves' ability to heat up quickly and apply intense heat to pans.

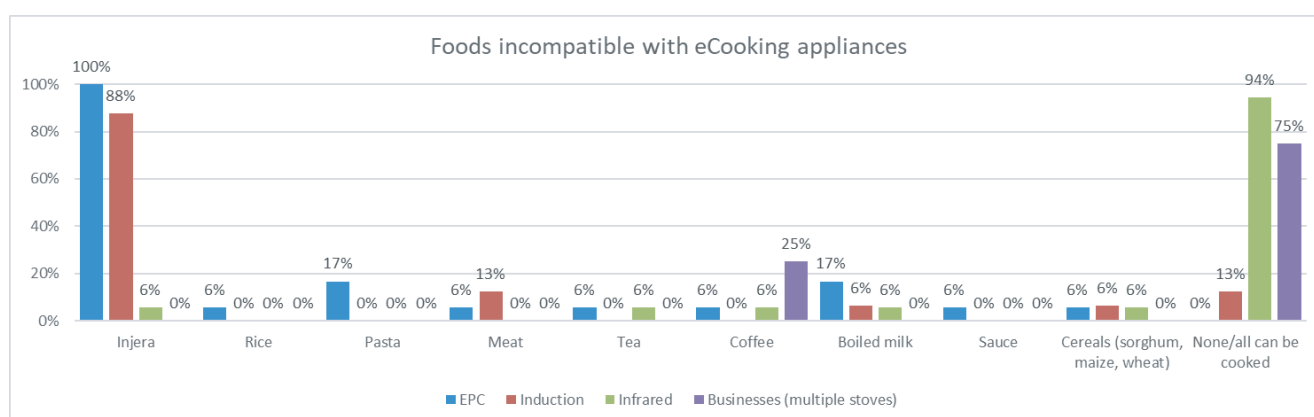


Figure 25: Food incompatibility with eCooking appliances.

The eCooking appliances were perceived as highly compatible with cooking most foods, specifically rice, pasta, meat, tea, coffee, boiled milk, sauce and cereals. There was a drastic divergence of opinion regarding injera, with EPC and induction stove users almost all finding the appliances incapable of cooking this food, compared to just 6% of infrared users. This, again, can be attributed to pre-existing pan compatibility with the infrared stove. This led to 94% of infrared users saying that all foods can be cooked with the appliance versus no EPC users and 13% of induction stove users.

4.1.2.12 Perceptions and Willingness to Pay

All the stoves consistently rated highly (above 3.8, out of 5) in their ease of operation, food taste, and food smell. However, they rated relatively low (between 1.8 to 2.0, out of 5,) in their ease of maintenance.

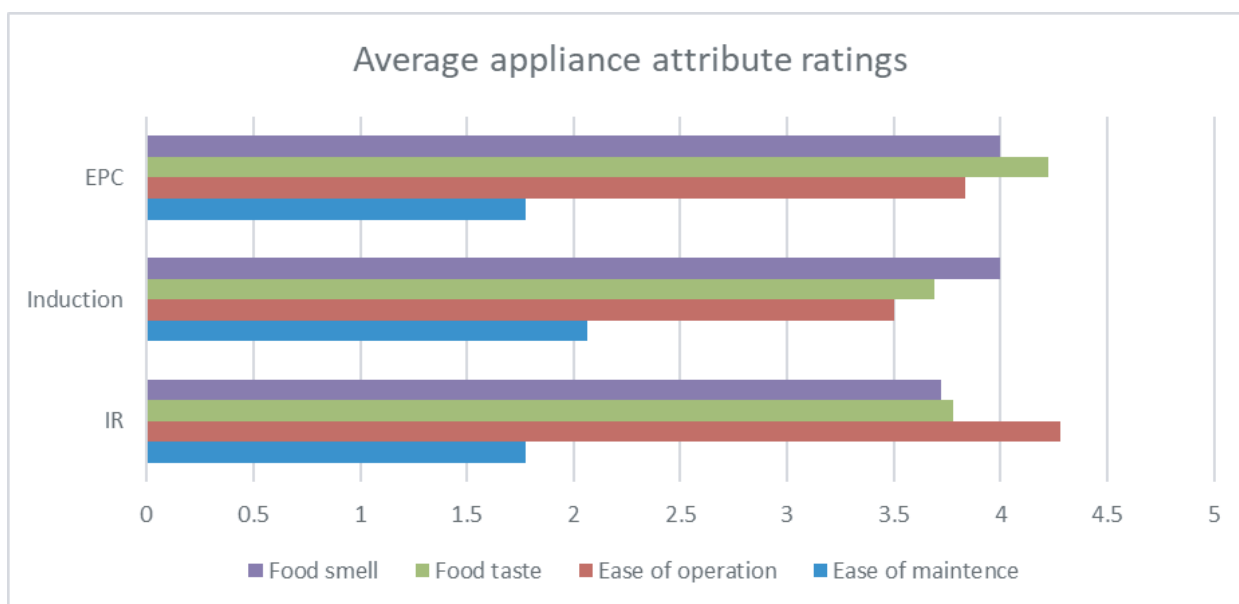


Figure 26: Average appliance attribution ratings.

The stoves appliances rated quite high (above 3.7 out of 5) for various environmental, social, and health benefits they offered.

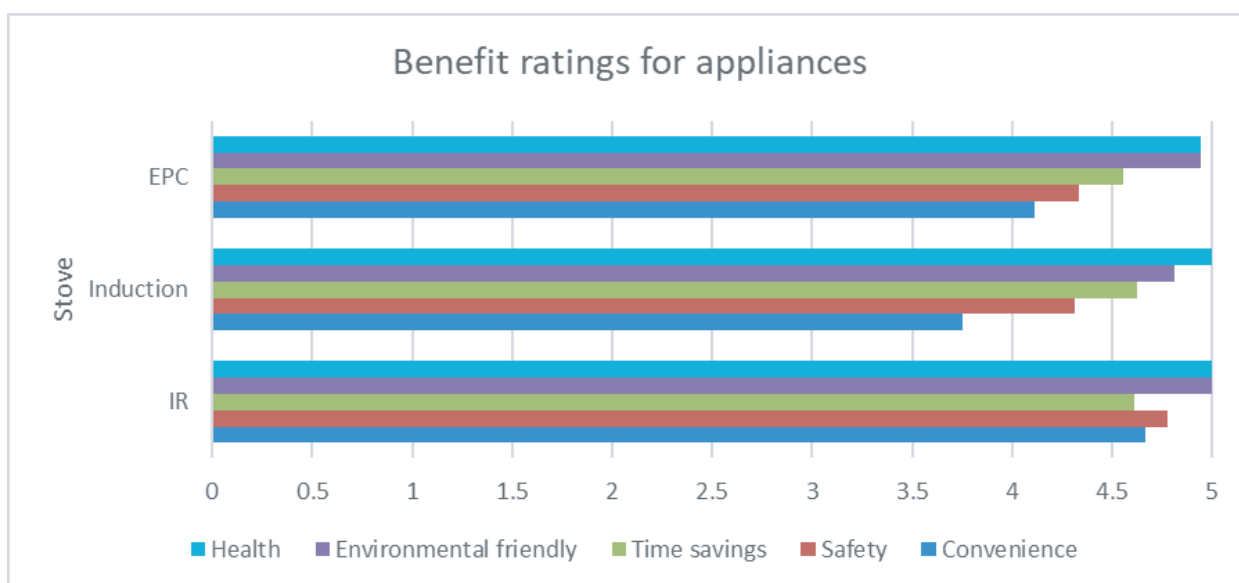


Figure 27: Benefits of appliances.

The net promoter score was high, with all of the IR treatment group participants, 81% of the induction group participants, and 89% of the EPC treatment group participants stating they would recommend their respective eCook stoves to others.

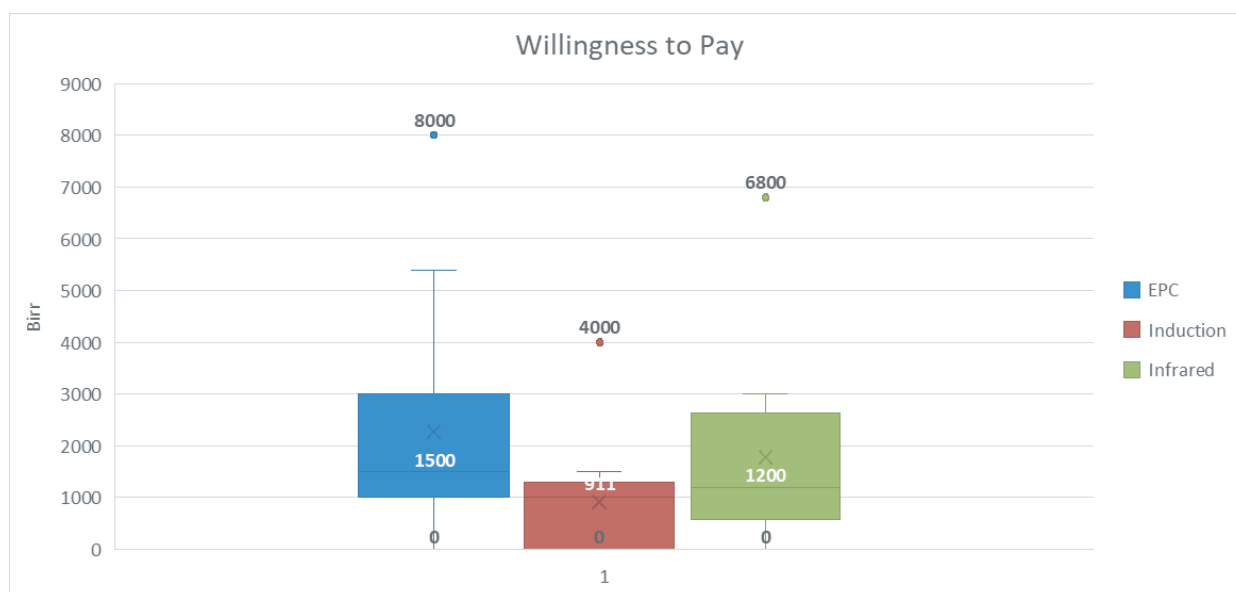


Figure 28: Self-reported willingness to pay for appliances.

Median willingness to pay was highest for the EPC (1500 birr, 11% of the purchase price paid by Mercy Corps), followed by the infrared stove (1200 birr, 12% of the price) and the induction stove (911 birr, 18% of the price). These figures are substantially below the appliance and pan values. Interestingly, these stated willingness to pay (WTP) prices are also lower than the subsidized prices (20% of the purchase price) offered at the end of the study, which almost all participants chose to purchase the stoves at. This shows the difference between stated and actual willingness to pay and shows the need for better methodologies to determine the subsidy need.

Only 33% of the infrared treatment group participants, 6% of the induction group participants, and 11% of the EPC treatment group participants were willing to purchase their respective appliances at their unsubsidized prices.

4.1.3 Exit Survey

4.1.3.1 Impacts of free electricity on usage

Most (68%) of intervention participants reported that having access to free electricity had no impact on their use of appliances other than the electric stoves, with 25% using other appliances less and 13% using them more. By contrast, 80% of participants said they cooked more with electricity during Phase 3. No participants reported increases in their use of other fuels in Phase 3, and 82% said they used less of their other fuels due to having free electricity. The biggest change was in the infrared group, where two-thirds (61%) of appliance recipients said used exclusively the infrared stove during Phase 3. No EPC or induction stove users reported exclusive use (Figure 29).

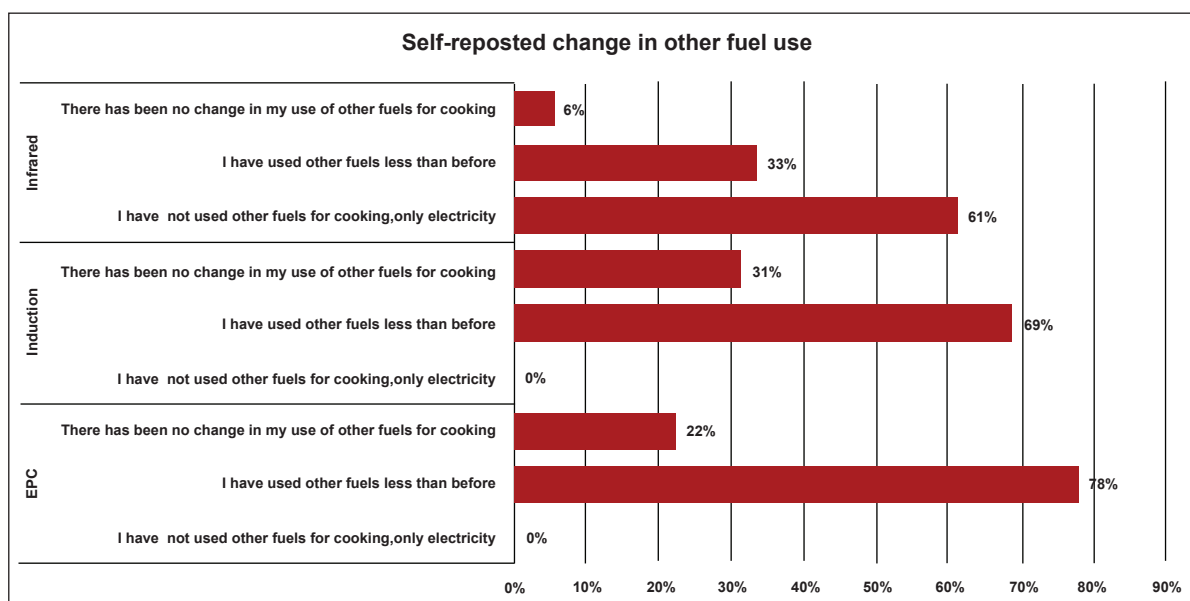


Figure 29: Self-reported change in fuel use during Phase 3.

Phase 3. No EPC or induction stove users reported exclusive use (Figure 29).

There were mixed perceptions about the quality of electricity supply during Phase 3. 57% reported no change compared to Phase 2, whilst 18% believed that electricity was more unreliable and 25% more reliable. Three-quarters of participants (73%) believed that using the eCooking appliances did not affect the quality of their electricity supply.

While two-thirds of the participants (63%) did not take the liberty to experiment with new dishes due to the free electricity offerings, the most popular new dishes to try were boiling milk (29%), followed by meat, tea, cereals, pasta, sauce, suqaar, ful, coffee, maraw, rice and dinij (each tried by 20-25% of participants).

The provision of the appliances and free electricity significantly decreased fuel procurement time for the majority of the IR treatment group (89%), as it did for the induction stove group (75%), but had a smaller impact on the EPC treatment group (44%). No change in fuel procurement time was reported by a small percentage of EPC users (17%) and induction stove users (13%) but by no infrared stove users.

Similarly, the intervention decreased cooking time for more than half of the EPC treatment group (67%), as it did for the induction stove group and IR stove group (56% each). No change in cooking time was reported by a small percentage of participants across all three groups (17-28%). Interestingly, a small proportion of participants in the induction stove treatment group and the IR stove treatment group reported having significantly increased cooking time (6% and 11%, respectively).

The time saved was repurposed to a range of other activities as shown in Figure 30, notably spending time with family (79%) and caregiving (71%), completing chores faster (68%), more leisure time (54%) and cooking more food (48%). This alludes to social and gender benefits arising from the eCooking intervention.

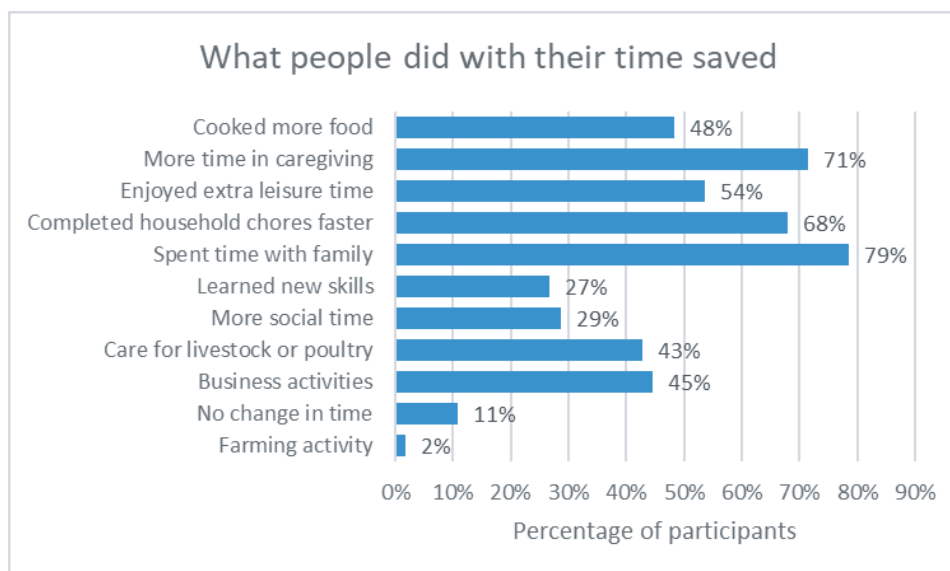


Figure 30: How time saved from eCooking was reallocated in Phase 3.

A third of participants (31%) said that responsibilities for cooking in their households changed after receiving the intervention. A small number said that the number of people cooking had decreased due to lack of knowledge about how to use the appliances, thus concentrating food preparation activities onto the main cook (5%). The rest reported positive impacts arising from the ability to cook faster and more flexibly.

4.1.3.2 Intentions after study end

After the end of the study, most participants planned to continue using the appliances as they did during the free electricity period (61%), with this intention concentrated amongst the infrared treatment group (72% compared to 56% for the EPC and 50% for induction). Others planned to continue using the appliances but less so (30%), whereas small proportions planned to use the appliances more (7%) or not at all (2%).

After the study the participants were offered the opportunity to purchase the stoves at an 80% discount. The discounted prices were perceived as somewhat affordable (34%) or very affordable (66%) by all participants, with minimal differences between the stove groups. Almost all (96%) planned to purchase the stoves at discounted prices. However, if the subsidies were removed, most participants across all the treatments had no intention of buying the appliances at their full prices (89% EPC, 69% induction stove with 13% missing data, and 94% infrared stove).

4.1.3.3 Market knowledge

Most (88%) of participants said they purchase their electrical appliances from Wajale, which is located in Somalia roughly 18kms from Sheder. The local field team reported that appliances in Wajale are cheaper than in Addis Ababa, Sheder or nearby Jijiga. More than half (54%) of participants were unsure whether the study appliances were available in the local markets, whereas a third (34%) were confident of their absence. Almost half (43%) were confident that the study appliances could not be purchased for lower amounts of money locally and the remainder (57%) were unsure.

More than three-quarters of respondents (77%) did not believe that people in Sheder would be willing to take out loans to purchase eCooking appliances, whereas a fifth (21%) believed the opposite. When asked their opinions on different payment modalities, participants showed overwhelming preferences for pay-as-you-go models (preferred by 84% of participants, Figure 31). Most would prefer Mercy Corps to manage payment and appliance distribution (84%) rather than UNHCR (7%) or other organisations in the camp (9%).

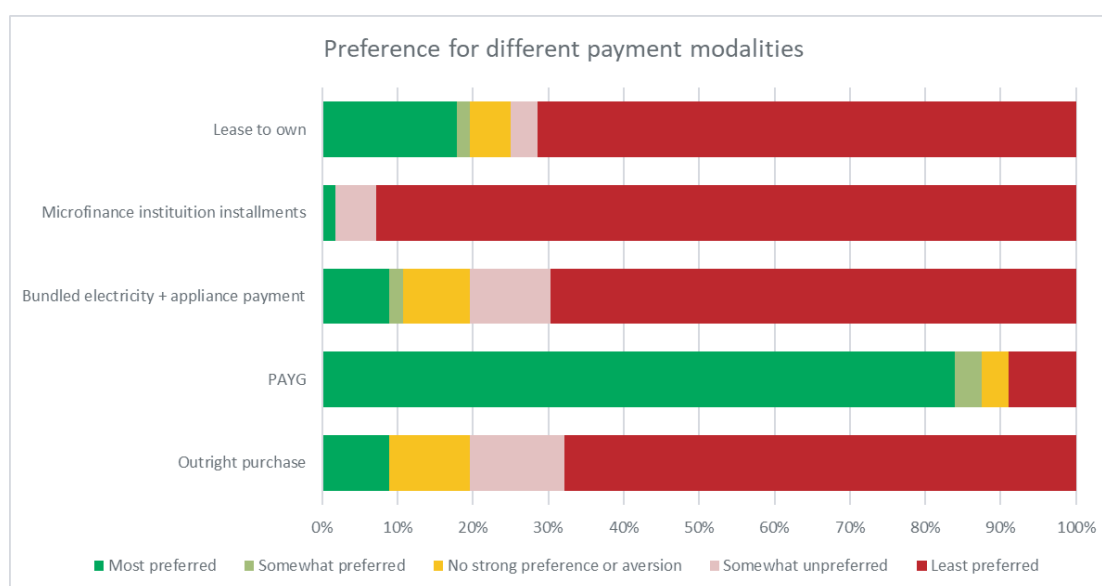


Figure 31: Preference for different payment modalities for eCooking appliances.

4.2 Metered Data

4.2.1 Changes in use of electricity

Figure 32 below shows how electricity use changed across the four groups and three phases. All households used more electricity for non-cooking end uses in both Phases 2 and 3 than in Phase 1. The volumes of electricity used in Phase 2 mirrored the appliance efficiencies and adoption levels revealed in the cooking diaries; amongst the household participants, the EPC group showed the smallest growth in electricity used for cooking, (from 28% to 29% of all electricity consumption in Phase 2 compared to Phase 3), followed by the induction stove (Phase 2: 59%; Phase 3: 76%), with the infrared stove using the most power in Phase 2 (Phase 2: 65%; Phase 3: 76%). Levels of non-cooking electricity use for the businesses (all of whom had two different appliances) was remarkably similar to the households, and the quantity of electricity used for cooking were less than the household infrared group. Electricity used for cooking grew substantially for Phase 3 for all groups other than the household EPCs.



Figure 32: Metered electricity use by group across the three phases. The percentages show the average proportion of electricity consumption on cooking in each phase.

4.2.2 Time of cooking

Figure 33 shows load curves for the households and businesses in Phases 2 and 3. The households showed clear cooking peaks at 7am (breakfast), 12.30pm (lunch) and 7pm (dinner). In Phase 2, the infrared group tended to use their stoves most at breakfast, whereas the induction and EPC groups peaked more at lunch and dinner. In Phase 3, the infrared stove and EPCs were used equally across all meals, whereas the induction stove continued to be preferred at breakfast and dinner. The mealtime peaks were less clear for the businesses, possibly due to the paucity of data behind the graphs (which drew upon a fifth of the number of participants as the household groups). The graphs reveal long business hours with cooking taking place from 6am to midnight.

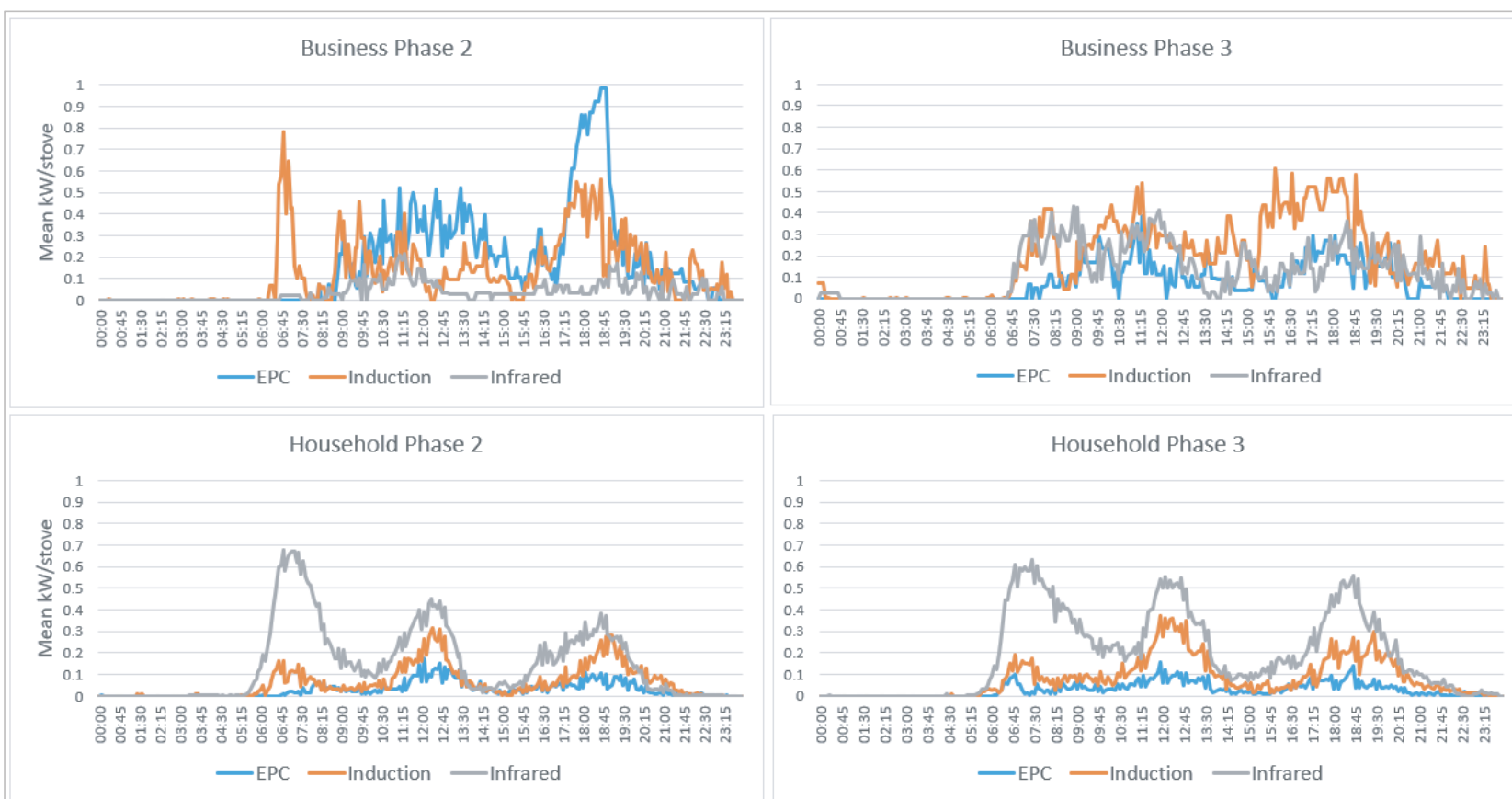


Figure 33: Load curves for each group across the three phases.

4.2.3 Changes in appliance use

Table 4 below presents the median values across the phases and groups for time spent cooking per day, energy used per day and number of cooking events per day.

Table 4: Changes in appliance use in Phase 2 and Phase 3.

Median values	Phase	HH_EPC	HH_infrared	HH_induction	Business
Time spent cooking per day (mins)	Phase 2	21.4	76.5	29.1	63.2
	Phase 3	42.75	226.1	81.7	112.6
Energy used per day (kWh)	Phase 2	0.24	1.25	0.66	1.23
	Phase 3	0.69	4.69	1.65	2.87
Cooking events per day	Phase 2	1.31	1.94	1.5	3.28
	Phase 3	3.5	4.25	3.94	6.5

Figure 34 shows that the time spent cooking per day increased across all the groups in Phase 3 compared to Phase 2 but that there were large differences in both the absolute amounts of time spent cooking between appliances and the magnitude of the change across phases. For the household EPC group, the median amount of time spent cooking doubled (Phase 2: 21 minutes; Phase 3: 43 minutes). The household infrared group roughly tripled (Phase 2: 77 minutes; Phase 3: 226 minutes) as did the induction group (Phase 2: 29 minutes; Phase 3: 82 minutes). The business group also doubled but had low amounts of time spent cooking with electricity given the amount of food they produced overall (Phase 2: 63 minutes; Phase 3: 113 minutes). Across all groups other than the EPC, the interquartile range was far larger in Phase 3, showing how removing affordability barriers resulted in large variation in how the stoves were used.

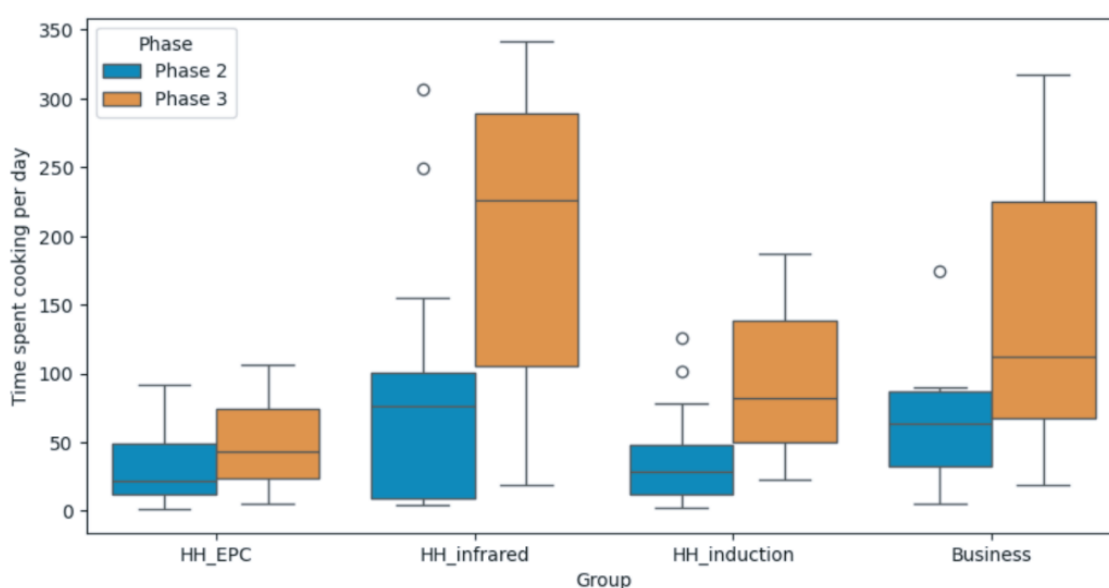


Figure 34: Time spent cooking per day across groups and phases.

The trends in Figure 34 are mirrored by those in Figure 35, which shows how energy use varied across the groups and phases, suggesting a roughly linear relationship between cooking time and energy used. The Phase 2 figures reflect appliance efficiency, with the infrared stove using five times as much power as the EPC and twice the power of the induction stove. This has important implications for the HumEn minigrid's capacity to support different appliances, which is explored further in [24].

Comparing between the phases revealed that household EPC energy use tripled in Phase 2 compared to Phase 3 (Phase 2: 0.24 kWh/day; Phase 3: 0.69 kWh/day), infrared quadrupled (Phase 2: 1.25 kWh/day; Phase 3: 4.69 kWh/day) and induction more than doubled (Phase 2: 0.66 kWh/day; Phase 3: 1.65 kWh/day). Business energy consumption increased by a factor of 2.3 (Phase 2: 1.23 kWh/day; Phase 3: 2.87 kWh/day).

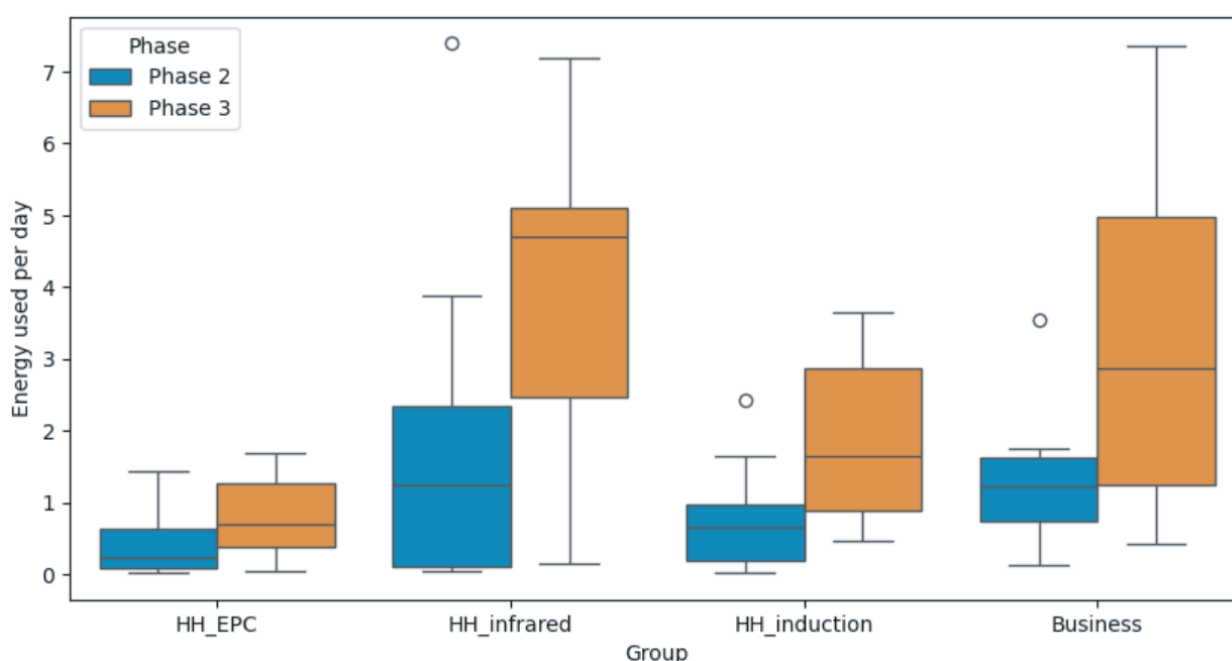


Figure 35: Electricity used per day across groups and phases.

Figure 36 shows that the number of cooking events per day roughly doubled for each of the groups in Phase 3 compared to Phase 2. The number of household EPC cooking events increased by a factor of 2.7 (Phase 2: 1.3 events/day, Phase 3: 3.5 events/day). The equivalent increases for household infrared were a 2.3 times increase (Phase 2: 1.9 events/day; Phase 3: 4.3 events/day), for household induction was a 2.6 times increase (Phase 2: 1.5 events/day; Phase 3: 4 events/day) with a 2 times increase for businesses (Phase 2: 3.3 events/day; Phase 3: 6.5 events/day). These figures demonstrate a more limited variation in cooking events than cooking time or energy, both in terms of the absolute numbers in phase two and the changes in phase 3, verifying that energy intensity varied between the appliances in line with their specifications.

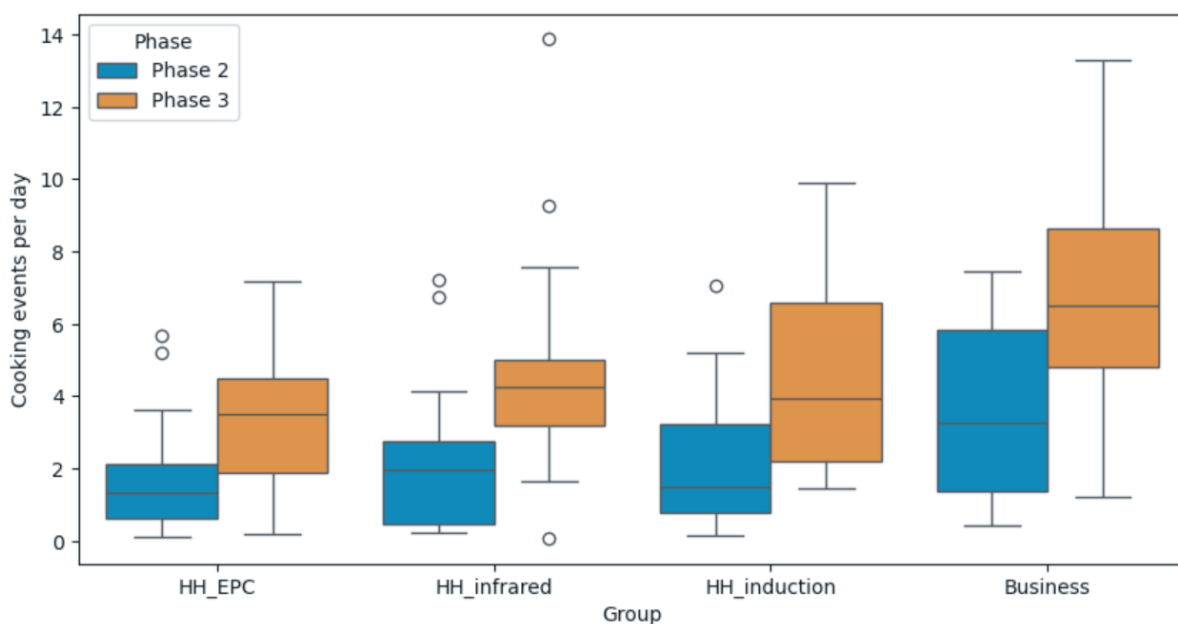


Figure 36: Number of electrical cooking events per day across groups and phases.

4.3 Cooking Diaries

4.3.1 Households

Fuel purchases

Participants recorded the weights and prices of fuel purchases in the cooking diaries, allowing for an analysis of fuel prices. Figure 37 shows the unit prices (birr/kg) for charcoal and firewood, which varied widely, with a median price of 47 birr/kg for firewood and 70 birr /kg for charcoal (Table 5).



Figure 37: Firewood and charcoal unit prices and purchase quantities

Table 5 shows that firewood tended to be purchased in larger quantities (median = 3.1 kgs) than charcoal (median = 1.9kg), although the purchase frequencies were similar (charcoal: median purchase frequency = 4.4 days, firewood: 5.2 days). Charcoal was almost always purchased (96% of the time) whereas firewood tended to be gathered for free (purchased 31% of the time).

Table 5: Purchase patterns for charcoal and firewood.

	Mean price (birr/kg)	Mean price (birr/kg)	Mean purchase qty (kg)	Mean purchase qty (kg)	Mean purchase frequency (days)	Median purchase frequency (days)	Proportion purchased
Firewood	63	47	5.8	3.1	9.0	4.4	31%
Charcoal	68	70	6.0	1.9	7.7	5.2	96%

Foods eaten

Table 6 shows the top ten foods eaten at breakfast, lunch, dinner and outside of meals. The mean number of meals eaten each day was 2.9 and the mean non-meal foods 0.4. Across the board, food was cooked from fresh for each meal (98% of items logged in the cooking diaries) and a median of eight people ate at each meal.

Table 6: Most frequently prepared household foods.

BREAKFAST			LUNCH			DINNER			NON-MEAL FOODS		
food	count	%	food	count	%	food	count	%	food	count	%
Tea	1508	42%	Bariis	832	34%	Tea	494	18%	Tea	346	57%
Canjeero	1228	34%	Suugo	475	19%	Suugo	374	14%	Caano	39	6%
Suugo	257	7%	Baasto	345	14%	Baasto	330	12%	Boiled water	35	6%
Injera	209	6%	Rice	134	5%	Bariis	257	9%	Boorash	31	5%
Sauce	52	1%	Tea	107	4%	Misir	132	5%	Biyo	20	3%
Egg	45	1%	Sauce	69	3%	Beans	107	4%	Bun	19	3%
Boiled water	36	1%	Caano	47	2%	Canjeero	94	3%	Coffee	18	3%
Boorash	29	1%	Shigni	46	2%	Boorash	77	3%	Shaah	15	2%
Coffee	22	1%	Meat	42	2%	Sabaayad	75	3%			
Biyo	21	1%	Jibis	34	1%	Soor	59	2%			

Breakfast consisted of two different components. The most common breakfast foods were tea (featuring in 42% of breakfasts), canjeero (a fermented pancake-like flatbread, featuring in 34% of breakfasts). Other common foods included suugo (a red sauce eaten with pasta, canjeero or injera, 7%) and injera (6%).

Lunch usually consisted of two components. The most common lunch foods were bariis (a rice dish with vegetables and/or meat similar to East African or Indian pilau, featuring in 34% of lunches), suugo (featuring in 19% of lunches) and baasto (pasta with meat sauce, featuring in 14% of lunches). Other popular lunchtime foods included plain rice (5%), tea (4%) and sauce (3%).

Dinner also normally had two components but consisted of a wider variety of foods than breakfast or lunch. The most common dinner foods were tea (featuring in 18% of meals), suugo (14%), baasto (12%), bariis (9%), misir (lentil soup, 5%) and beans (4%).

Some cooking events were also recorded outside of meals, on average taking place on alternate days. The majority of these non-meal cooking events were to prepare tea (57% of non-meal cooking events), caano (hot milk, 6%), boiled water (6%) and boorash (oat porridge, 5%).

Cooking events and fuel use

Participants recorded an average of 5.8 cooking events each day. Figure 38 shows there were minimal changes between the total number of cooking events each day for each phase for each group, suggesting that the eCooking intervention had little impact on the volume of cooking that occurred.

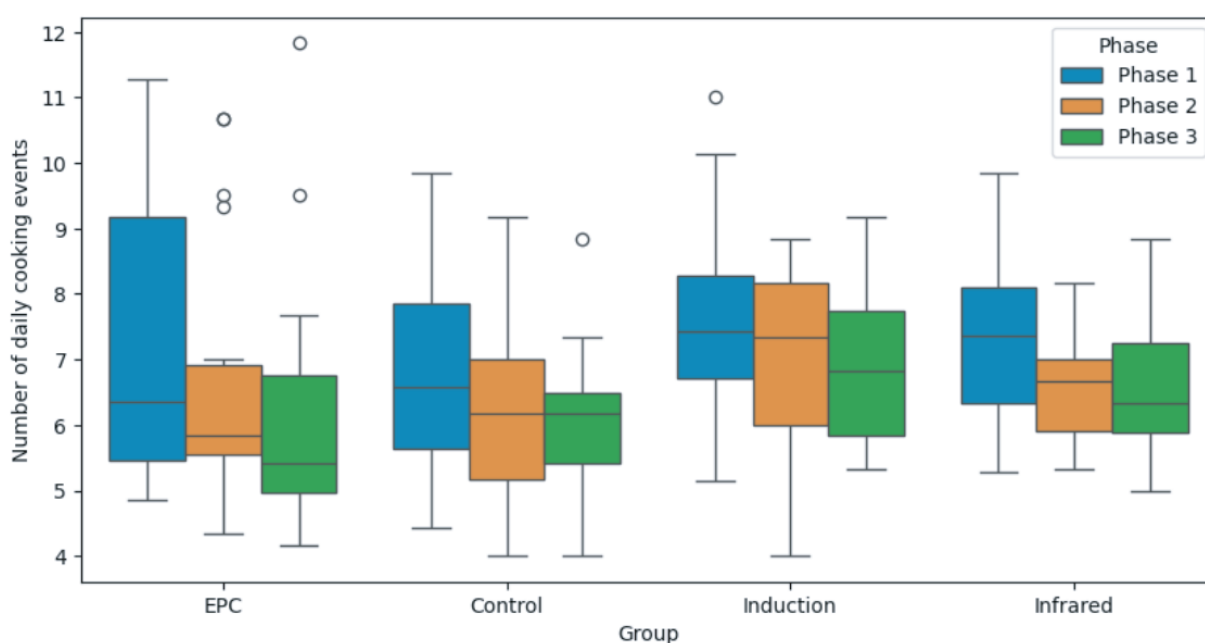


Figure 38: Number of daily cooking events across groups and phases.

However, there were drastic changes in the choice of fuels, as shown in Figure 39, Figure 40 and Table 7 below. In Phase 2, when households were paying for the electricity they used, the eCooking appliance displaced around a third of cooking activities, with the infrared stove being the most used (39% of cooking events), closely followed by the EPC (37%) and the induction stove (29%). In Phase 3, when electricity was made free, the infrared stove almost completely displaced all other fuels (used for 93% of cooking events), whilst use of the EPC and induction stove doubled (65% and 60% respectively).

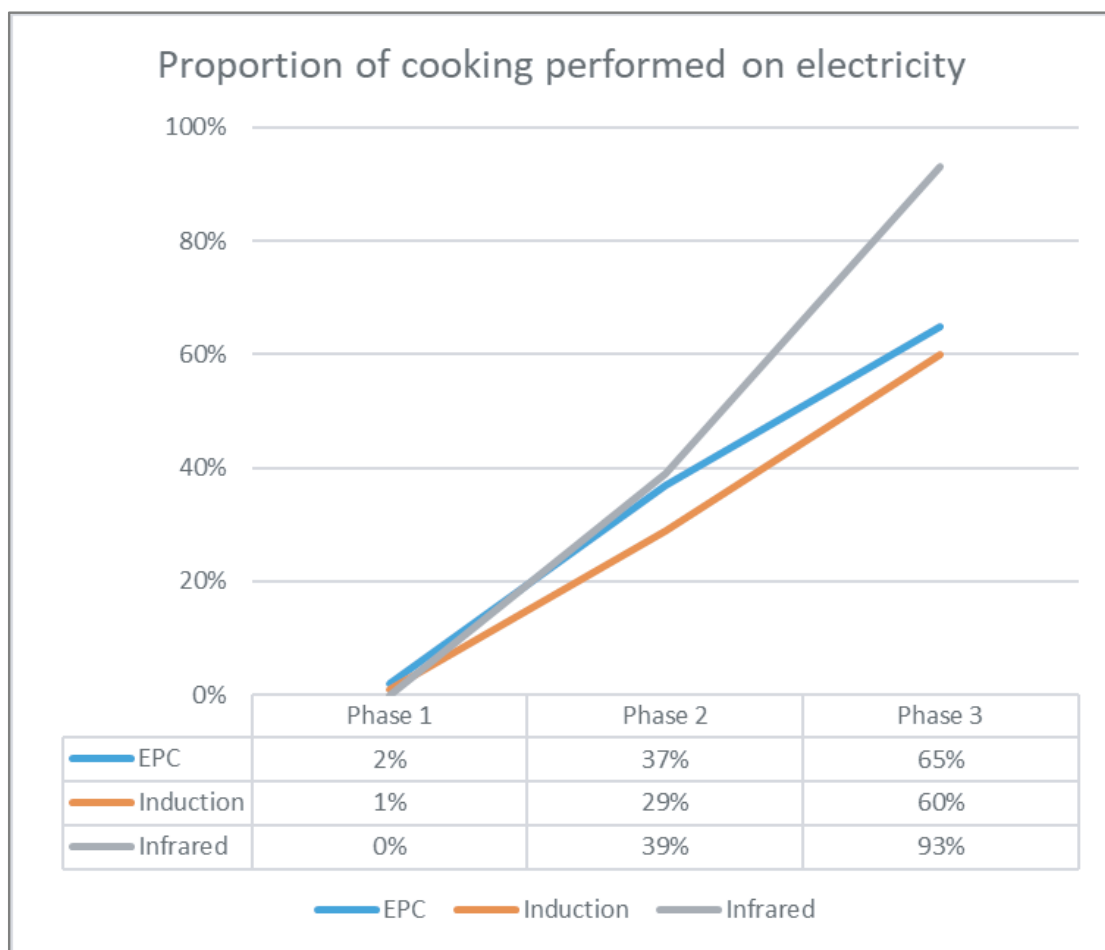


Figure 39: Proportion of cooking performed on electricity.



Figure 40: Breakdown of fuel use by number of cooking events across groups and phases.

Table 7: Breakdown of cooking events by fuel across groups and phases.

		Number of cooking events			Percentage of cooking events		
		Charcoal	Electricity	Firewood	Charcoal	Electricity	Firewood
Phase 1	Control	896	0	166	84%	0%	16%
	EPC	796	16	83	89%	2%	9%
	Induction	846	6	52	94%	1%	6%
	Infrared	907	3	4	99%	0%	0%
Phase 2	Control	537	3	170	76%	0%	24%
	EPC	363	267	88	51%	37%	12%
	Induction	376	203	128	53%	29%	18%
	Infrared	359	267	52	53%	39%	8%
Phase 3	Control	479	9	204	69%	1%	29%
	EPC	208	436	28	31%	65%	4%
	Induction	245	394	17	37%	60%	3%
	Infrared	44	662	4	6%	93%	1%

Financial impacts

Figure 41 shows how participants' daily spend varied throughout the phases. Despite receiving no intervention, the control group's median cooking expenditure dropped from 149 birr/day to 101 birr/day (-32%) in Phase 2 compared to Phase 1, before increasing to 114 birr/day (13%) in Phase 3. This suggests that external factors could have affected the cost of cooking in Sheder during the camp, such as temporal shifts in diet or changes in prices of cooking fuel. The graphs also show that the baseline expenditures for the four groups varied widely, with the median ranging from 105 birr/day for the induction group to 206 birr/day for the EPC group. This could be due to a wide range of factors such as family size, dietary preferences and stove type.

EPC users' median cooking expenditure dropped from 206 birr/day in Phase 1 to 100 birr/day in Phase 2 (-51%). It reduced further to 67 birr/day in Phase 3 (-33% compared to Phase 2). The induction group's median expenditure experienced smaller reductions from 125 birr/day in Phase 1 to 93 birr/day in Phase 2 (-26%), followed by a larger drop to 51 birr/day in Phase 3 (-45%). Finally, the infrared users' median cooking expenditure fell minimally from 105 birr/day in Phase 1 to 101 birr/day in Phase 2 (-4%), reflecting the inefficiency of this appliance. However, in Phase 3 expenditure fell to 0 birr/day (-100%) as almost all cooking activities were performed on this stove.

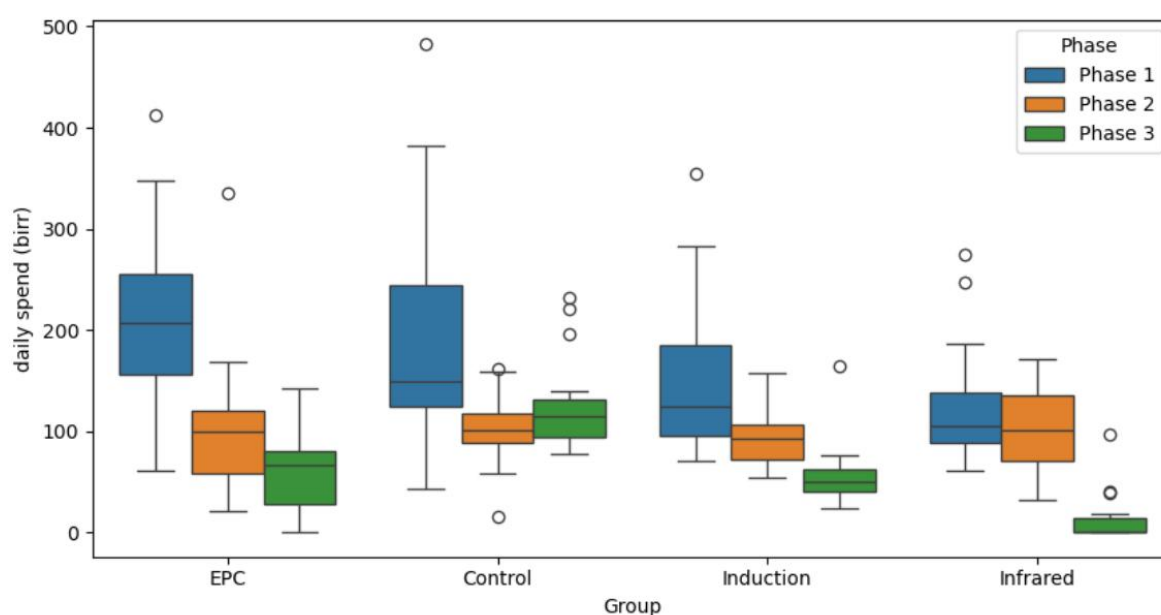


Figure 41: Total cooking expenditure across groups and phases.

Time impacts

Finally, we turn to the time impacts associated with the eCooking intervention. Figure 42 shows how participants' daily total time spent cooking varied throughout the phases. It shows that the eCooking appliances were associated with reduction in time spent cooking, although these were not as dramatic as the reductions in fuel expenditure (Figure 41), and varied little between Phases 2 and 3. The control group spent 11% less time cooking in Phase 2 (297 mins/day) compared to Phase 1 (332 mins/day) and almost the same amount of time cooking in Phase 3 (300 mins/day). The EPC group spend 5% less time cooking in Phase 2 (269 mins/day) compared to Phase 1 (283 mins/day) with a further reduction of 7% less time in Phase 3 (249 mins/day). The effects were larger for the induction and infrared stoves; the induction group spend 18% less time cooking in Phase 2 (235 mins/day) compared to Phase 1 (288 mins/day) with a further reduction of 7% less time in Phase 3 (219 mins/day). Infrared users spent 14% less time cooking in Phase 2 (277 mins/day) compared to Phase 1 (321 mins/day) but 3% more time cooking in Phase 3 (286 mins/day).

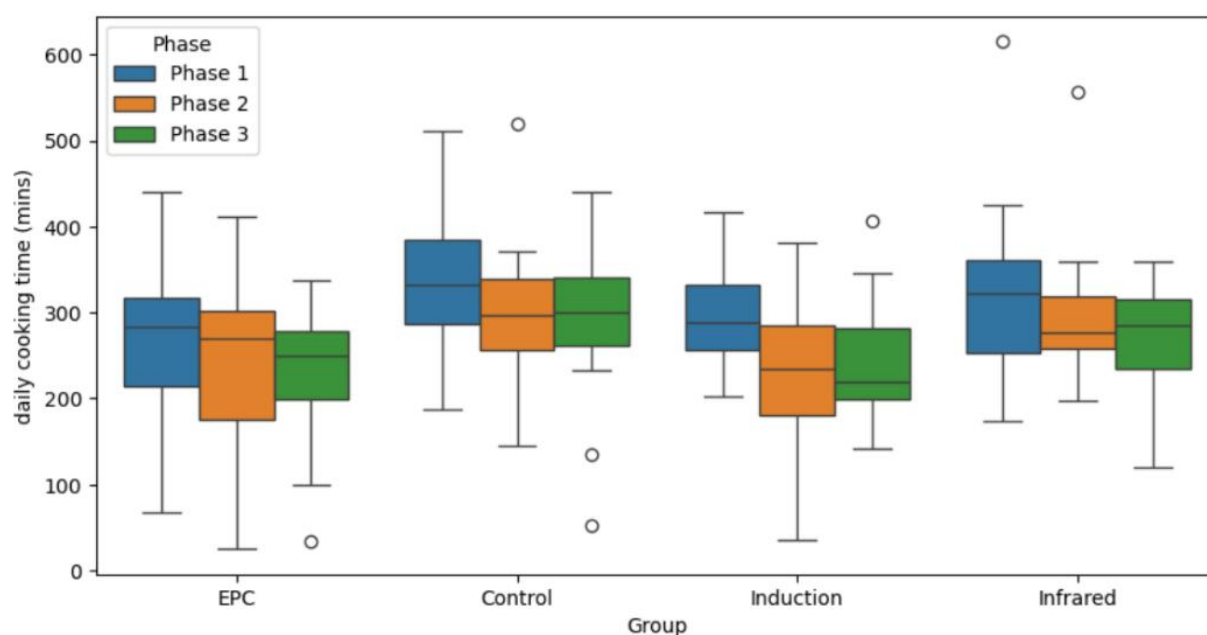


Figure 42: Daily time spent cooking by group and phase.

4.3.2 Businesses

Due to data quality issues, it was not possible to analyse fuel purchases, financial impacts for the business users or time savings in procuring fuel.

The number of cooks varied by business and consisted mostly of females. Business 1 had three female cooks; Business 2 had one male cook and 1-3 female cooks depending on the day; Business 3 had 0-1 male cooks and 3-4 female cooks' and business 4 had 1 male cook and 0-1 female cooks.

The businesses had vastly differing levels of custom. The average number of customers served per day varied from 127 to 22 and the average daily takings from 1970 to 5650 birr (Table 8).

Table 8: Customers served and daily revenues for each business by phase.

		Business 1	Business 2	Business 3	Business 4
Daily customers served	Phase 1	118	27	124	22
	Phase 2	141	21	125	20
	Phase 2	121	23	133	24
Daily revenue (birr)	Phase 1	4907	2425	5000	2160
	Phase 2	5454	2900	5070	1800
	Phase 2	5670	2450	6890	1940

Foods eaten

Table 9 shows the top 16 foods recorded in the business cooking diaries, accounting for 80% of all dishes logged. The top three foods were ful (12% of all dishes recorded), tea (11%) and coffee (10%). These foods were eaten throughout the day and did not follow the same mealtime constraints as in households.

Table 9: Top foods prepared by businesses.

Ref	Food	Count	Percent	Ref	Food	Count	Percent
1	Ful	176	12%	9	Sanbusa	54	4%
2	Tea	154	11%	10	Canjeero	47	3%
3	Coffee	141	10%	11	Suqaar	40	3%
4	Pasta	97	7%	12	Misir	33	2%
5	Suugo	87	6%	13	Hariko	30	2%
6	Egg	77	5%	14	Shuro	26	2%
7	Dinji	74	5%	15	Baradho	22	2%
8	Bariis	70	5%	16	Potato	22	2%

Cooking events and fuel use

Participants recorded vastly different numbers of cooking events each day, ranging from a median of 8 (Business 2) to 36 (business 3). Figure 43 shows there were minimal changes between the total number of cooking events each day for each phase for groups 1, 3 and 4, suggesting that the eCooking intervention had little impact on the volume of cooking that occurred. However, business 2 saw a sharp jump in the number of median cooking events in Phase 3 (from 8 events in Phases 1 and 2 to 14 events in Phase 3).

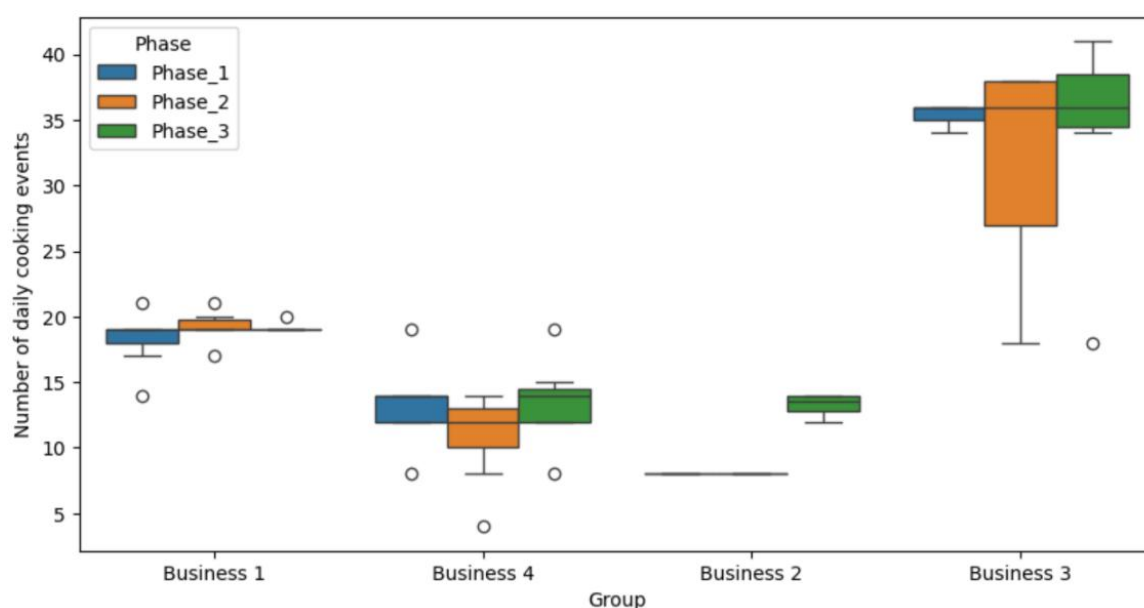


Figure 43: Daily cooking events for each business by phase.

The changes in the choice of fuels were less drastic for the businesses than for the households, as shown in Figure 45, Figure 44 and Table 10 below, and exhibited considerable variation. In Phase 2, when businesses were paying for the electricity they used, the eCooking appliances accounted for an extremely large range of cooking events (11-97% of total events). In Phase 3, when electricity was made free, the appliances for 3-71% of cooking events, with two of the four businesses showing a decrease in share of electric cooking compared to Phase 2. This suggests that fuel affordability was not the major factor driving fuel stacking for businesses.

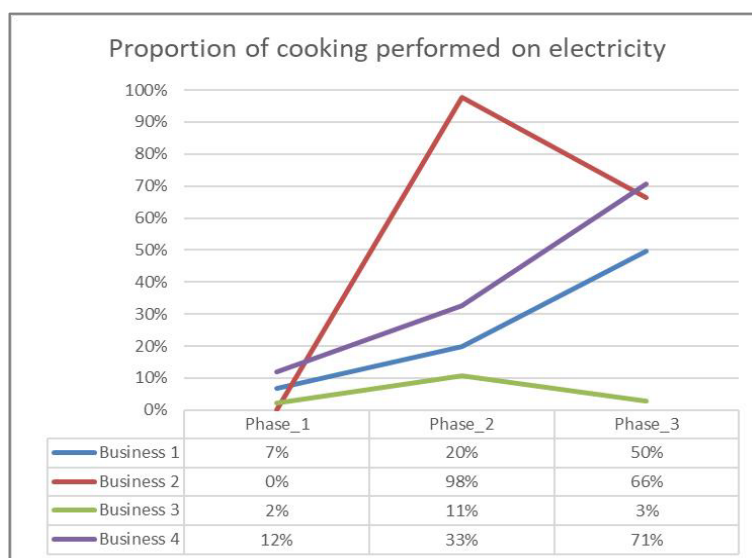


Figure 44: Proportion of cooking performed on electricity for each business across three phases.

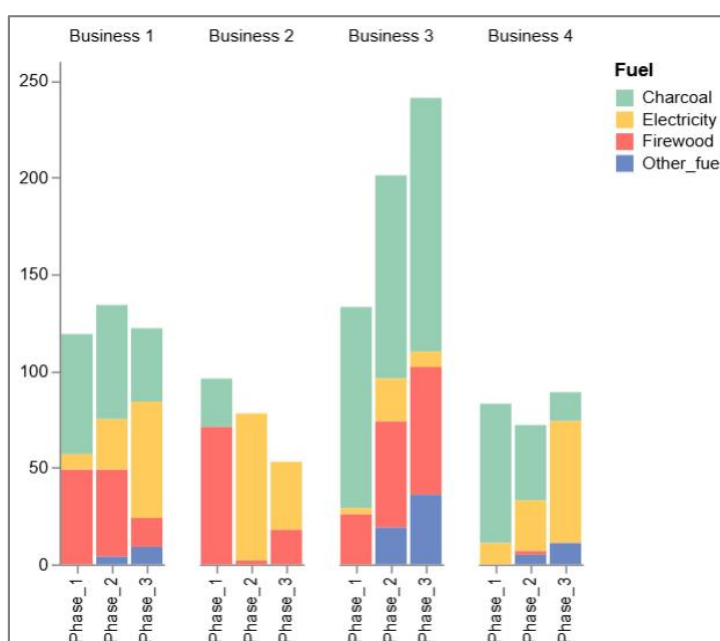


Figure 45: Breakdown of fuel use for each business by number of cooking events across phases.

Table 10: Cooking events for each business across three phases.

		Number of cooking events				Percentage of cooking events			
		Charcoal	Firewood	Electricity	Other	Charcoal	Firewood	Electricity	Other
Phase 1	Business 1	62	49	8	0	52%	41%	7%	0%
	Business 2	25	71	0	0	26%	74%	0%	0%
	Business 3	104	26	3	0	78%	20%	2%	0%
	Business 4	72	0	11	0	87%	0%	13%	0%
Phase 2	Business 1	59	45	26	4	44%	34%	19%	3%
	Business 2	0	2	76	0	0%	3%	97%	0%
	Business 3	105	55	22	19	52%	27%	11%	9%
	Business 4	39	2	26	5	54%	3%	36%	7%
Phase 3	Business 1	38	15	60	9	31%	12%	49%	7%
	Business 2	0	18	35	0	0%	34%	66%	0%
	Business 3	131	66	8	36	54%	27%	3%	15%
	Business 4	15	0	63	11	17%	0%	71%	12%

Time impacts

Figure 46 shows how time spent cooking varied across the businesses and phases. Unlike for the households, there was no clear emergent trend about how the eCooking appliance in Phase 2 and the free electricity intervention in Phase 3 affected the time spent cooking. This could be because of the relatively lower levels of eCooking adoption for the businesses and because time spent cooking was more strongly driven by the number of customers in a given week than by the fuel used.

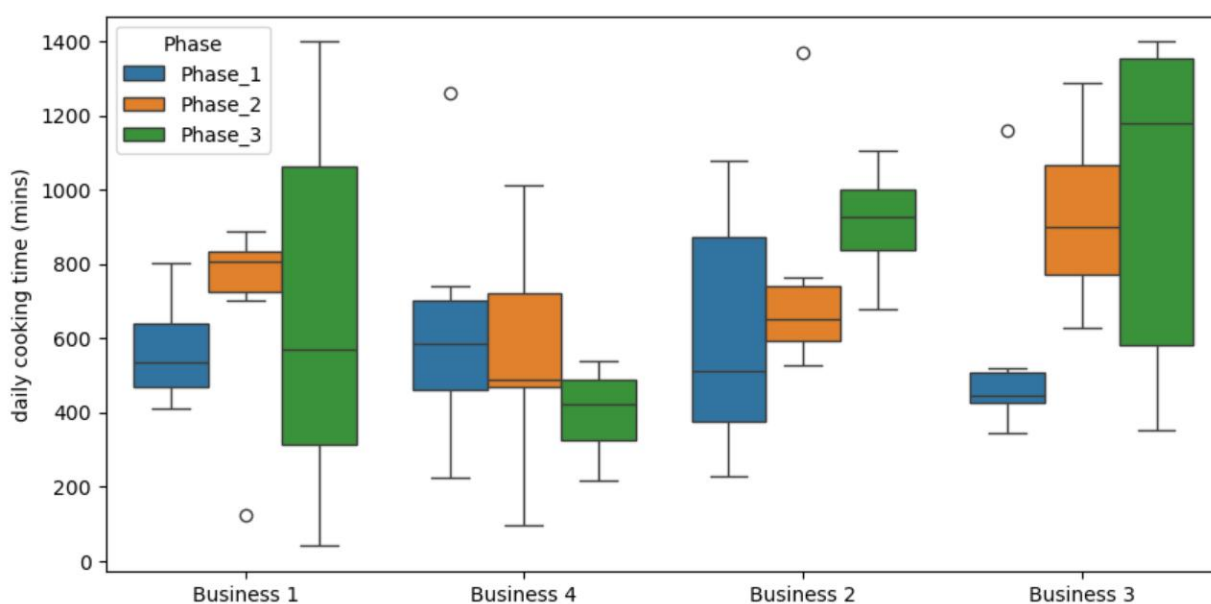


Figure 46: Changes in daily cooking time for each business across three phases.

4.4 Focus Group Discussions

The FGDs took place at the end of Phase 2, thus exploring participants' experiences using eCooking appliances under market-based conditions of paying for electricity. The discussions revealed strong interest among participants in eCooking adoption, particularly for infrared stoves, which were consistently rated highest in terms of versatility, cultural compatibility, and user satisfaction. EPCs were viewed as promising for their time savings and food quality improvements, though limited by their capacity and versatility. Induction stoves were perceived as least suitable for primary cooking due to cookware compatibility issues, taste concerns, and limited functionality; they were regarded as complementary rather than replacement appliances. Participants across all groups emphasised that fuel stacking with woodfuels would likely continue and that increased adoption of eCooking would depend on addressing interconnected technical, economic, and cultural barriers.

4.4.1 Overall acceptance and ease of use of eCooking appliances

Participants across all FGDs reported positive experiences with the eCooking appliances, though levels of acceptance varied significantly by appliance type and user group. Infrared stoves received the highest acceptance among both household and business users. Household participants consistently reported that infrared stoves enabled them to prepare all their daily meals without major difficulty, while business users emphasised their suitability for preparing traditional foods, particularly Somali injera. Across both groups, users reported minimal issues related to food compatibility when using infrared stoves.

EPCs received mixed responses. Household participants highlighted their usefulness for specific dishes, particularly beans and stews, but frequently noted limitations related to pot size, which constrained their ability to cook for large families. Business participants, by contrast, reported high satisfaction with EPCs due to significant time savings and improved cooking efficiency. Both groups noted improvements in food taste, attributing this to the absence of smoke and soot associated with charcoal cooking.

Participants were least satisfied with the induction stoves. Household participants reported substantial challenges related to incompatibility with traditional cookware, while business users indicated that induction stoves were only suitable for limited tasks such as boiling tea, preparing sauces, or cooking pasta. Several participants reported negative changes in food taste, which they associated with the use of thin or unfamiliar pots required for induction cooking.

4.4.2 Perceived benefits of eCooking appliances

Participants identified multiple benefits associated with eCooking across all appliance types. Significant time savings were widely reported for infrared stoves and EPCs, while induction stoves were associated with moderate time savings for specific tasks. Cleanliness emerged as a major benefit across all groups due to the absence of smoke, ash, and soot when using electric appliances. Related health benefits were frequently cited, particularly reduced exposure to smoke and improved cooking environments.

Perceptions of food quality varied by appliance. Infrared stove users reported limited noticeable change in taste compared to traditional cooking. EPC users noted improved food quality, particularly for dishes that require long cooking times. In contrast, induction stove users frequently experienced negative changes in taste, which they linked to uneven heating and unsuitable cookware.

Infrared stoves were perceived as highly versatile and suitable for a wide range of traditional foods. EPCs were considered moderately versatile, while induction stoves were widely regarded as having limited relevance beyond specific cooking tasks.

4.4.3 Barriers to adoption

Technical and design barriers

Technical and design-related challenges were raised across all FGDs. Pot compatibility emerged as the most frequently cited barrier, particularly for induction stoves and for business users requiring large commercial cookware. Participants also highlighted the limitation of single-burner appliances, which constrained their ability to prepare multiple dishes simultaneously; this concern was raised by all business users and by households using infrared stoves. Capacity limitations were reported across all appliance types, with household participants noting that pots were often too small for family meals, with business users stating that available appliances could not accommodate commercial-scale pots.

Economic barriers

Economic concerns were persistently raised by both households and businesses. Participants across all groups perceived electricity costs to be high, which influenced their willingness to rely on eCooking appliances for daily cooking.

The pilot provided end-users with appliances at no upfront cost, but this would be unrealistic at scale, so the FGD's also sought participants' insights on how best to overcome the acquisition hurdle. Participants expressed strong sensitivity to upfront costs and strongly preferred instalment-based payment options over upfront purchases. Tariff integration or repayment through electricity bills was widely rejected. Households also reported limited ability or willingness to access formal credit mechanisms. Willingness-to-pay ranges varied by appliance type, with infrared stoves generally perceived as offering reasonable value, EPCs showing a wider acceptable price range, and induction stoves associated with lower perceived value.

Cultural and behavioural barriers

Cultural and behavioural factors also shaped adoption patterns. Participants reported that induction stoves were incompatible with the preparation of key traditional foods such as Somali injera and soor/ugali, while infrared stoves were perceived as capable of supporting these cooking practices. Across all FGDs, participants indicated continued use of charcoal alongside eCooking appliances due to technical and capacity limitations. Differences in behaviour change patterns were also observed within households, with younger members adopting eCooking faster than older members, who tended to prefer traditional methods.

4.4.4 Enablers for adoption

Participants identified several enablers that would support the successful adoption of eCooking. Immediate needs included design improvements such as dual-burner appliances, larger and more compatible pots, and improved pot quality, particularly for induction stoves. Economic enablers included instalment payment options, subsidies, or reduced appliance prices. Infrastructure-related enablers included reliable electricity supply, warning systems for low meter balances, availability of local technical support, and access to spare parts.

Longer-term enablers discussed in FGDs included peer-to-peer demonstrations in communal spaces such as water points and markets, continued support beyond initial training, improved access to financial services, and the use of existing social networks to disseminate information and build trust.

4.5 Stove Purchases

At the end of the pilot, participants were offered the opportunity to purchase the stoves they had been using at an 80% discount (see table below). There was high willingness to pay at this price; just three participants declined, consisting of one from each stove group. The control were offered an allocation of stoves at the subsidised price with half of them receiving a 6L EPC and half an induction stove. They all chose to purchase the appliances.

Appliances	Price (ETB)	Price (USD)	Remark
6 Litre Electric Pressure cooker	2,300.00	18.55	80% Subsidized
8 Litre Electric Pressure cooker	2,600.00	20.97	80% Subsidized
Single burner Infrared Stove	1,200.00	9.68	80% Subsidized
Single burner medium size induction stove with Pot	1,300.00	10.48	80% Subsidized
Single burner large size induction stove with Pot	1,500.00	12.10	80% Subsidized

5.

Discussion

5.1 Baseline cooking practices in Sheder

5.1.1 Household cooking patterns

Baseline survey and cooking diary data reveal a heavy reliance on solid biomass fuels for household cooking in Sheder, with charcoal emerging as the dominant primary fuel. Nearly 90% of households reported charcoal as their main cooking fuel, while a smaller proportion continued to rely on firewood, often burned in three-stone fires. Stove and fuel stacking was common; although most households reported using one primary stove, over a quarter used two, reflecting a need to balance cooking speed, pot size, and fuel availability across different dishes.

Cooking diaries and surveys indicate that staple meals such as rice, beans, pasta, and stews dominate daily cooking routines. These dishes frequently involve long boiling times, particularly for beans and rice, which drives high fuel consumption and prolonged exposure to smoke. Charcoal was typically purchased weekly or monthly, with expenditures representing a substantial share of household income. While some households collected firewood for free, this practice entailed significant time costs, with several participants reporting up to several hours per collection trip. The diaries and survey further highlight that cooking is often conducted indoors or in semi-enclosed kitchen spaces, exacerbating exposure to indoor air pollution.

Households' reliance on biomass fuels is reinforced by the multiple non-cooking benefits these fuels provide. Traditional stoves enable multitasking, simultaneous preparation of multiple dishes, space heating, and cooking during religious festivals and communal events. This shows how cooking practices are embedded within broader household routines and social functions, making them resistant to simple one-for-one fuel substitution.

Health and comfort impacts are already pronounced at baseline. Over 90% of household cooks reported poor or very poor air quality while cooking, with frequent symptoms including eye irritation, headaches, coughing, and shortness of breath occurring multiple times per day. Thermal discomfort was also reported to worsen during cooking, particularly in enclosed spaces. These findings reveal that current cooking practices impose significant health burdens, while also shaping expectations around stove size, power, and flexibility that any alternative cooking technology must meet.

5.1.2 Businesses cooking patterns

Commercial cooking practices in Sheder display even higher intensity and energy demand than household cooking. All surveyed businesses relied on charcoal as a primary fuel, with a smaller subset also using firewood to meet high-volume or high-heat cooking needs. Unlike households, all businesses used improved charcoal stoves, reflecting both higher cooking loads and greater incentives to invest in fuel efficiency.

Menus across businesses were relatively homogeneous, with rice and pasta served universally and forming the core of daily sales. Cooking processes were dominated by boiling and steaming, often combined with frying, reflecting the need to prepare large quantities of food quickly and consistently.

Cooking typically took place inside the main business premises, often without dedicated ventilation, resulting in significant deterioration of air quality during operating hours. Nearly all businesses reported poor or very poor air quality while cooking, and cooks frequently experienced respiratory and eye-related symptoms multiple times per day. Interestingly, thermal comfort was often reported to improve during cooking, particularly during colder seasons, as biomass stoves also functioned as a source of space heating, an ancillary benefit that electric alternatives may not replicate.

Although all businesses were connected to the minigrid, only a minority reported using electric cookstoves at baseline, and these were generally limited to specific tasks rather than primary cooking. This highlights a clear distinction between access to electricity and its productive use for cooking, especially in commercial settings where appliance compatibility is particularly critical.

5.2 Adoption of eCooking practices in Sheder: Trends and preferences

Across both households and businesses, adoption of eCooking in Sheder was shaped less by resistance to change and more by the alignment between technology, cooking practices, and economic realities. Phase 2 demonstrated cautious but meaningful uptake under real tariff conditions, while Phase 3 revealed high latent demand when electricity costs were removed. However, persistent fuel stacking across both groups implies that eCooking adoption is constrained by appliance design, cooking scale, and cultural practices as much as by affordability.

5.2.1 Household adoption practices

Comparing between the phases revealed that household EPC energy use tripled in Phase 2 compared to Phase 3 (Phase 2: 0.24 kWh/day; Phase 3: 0.69 kWh/day), infrared quadrupled (Phase 2: 1.25 kWh/day; Phase 3: 4.69 kWh/day) and induction more than doubled (Phase 2: 0.66 kWh/day; Phase 3: 1.65 kWh/day). The Phase 2 consumption figures are of the same magnitude as urban grid-based eCooking interventions elsewhere in Sub-Saharan Africa. This important and surprising finding contradicts widely held assumptions about the unviability of market-based clean cooking interventions in refugee settings.

Household adoption of eCooking in Sheder followed a gradual and conditional trajectory. During Phase 2, when eCooking appliances were introduced under standard electricity tariffs, cooking diaries reveal a substantial increase in electricity-based cooking events across all treatment groups, but persistent fuel stacking remained the dominant pattern. While electricity accounted for up to 37-39% of cooking events for EPC and infrared users, charcoal continued to be used for over half of all cooking activities, reflecting households' cautious integration of eCooking rather than wholesale substitution.

Survey responses and FGDs suggest that this partial adoption was driven by practical limitations. Households consistently reported that appliance size and single-burner configurations were insufficient for large family meals. Households often reverted to charcoal for long-boiling or large-volume dishes, while reserving eCooking appliances for faster or smaller tasks.

The eCooking appliance type strongly influenced adoption intensity. Infrared stoves achieved the highest and most consistent use across both Phase 2 and Phase 3, a pattern reflected in diary data showing the largest shift toward electricity-based cooking events and the steepest reduction in charcoal reliance, albeit the least dollar cooking energy cost reduction to the end user. FGDs attribute this to infrared stoves' compatibility with traditional cookware and their ability to support culturally important foods, including injera, and large pots. In contrast, induction stoves faced significant resistance due to pot incompatibility, leading to lower uptake and, in some cases, abandonment despite demonstrated time and cleanliness benefits. EPCs occupied an intermediate position, as they were highly valued for specific foods, especially beans and stews, but were constrained by pot size and limited versatility.

Phase 3 removed electricity cost barriers and revealed the upper bound of household eCooking adoption under current technological conditions. Cooking diaries show a dramatic increase in electricity-based cooking events, particularly among infrared users, for whom electricity accounted for over 90% of cooking activities. Median daily cooking expenditures for infrared

households fell to zero during this period, and time spent on fuel procurement declined sharply. However, even with free electricity, a full transition was not universal. A subset of households, especially among induction and EPC users, continued to rely on charcoal, revealing that cost alone does not determine adoption when appliance capacity and cooking flexibility remain constrained.

Metered data further illustrates the behavioural ceiling of household eCooking. Although cooking events increased substantially during Phase 3, median household electricity consumption for cooking remained modest compared to commercial users, suggesting that households actively managed load and avoided over-reliance on electric appliances. This aligns with survey findings indicating persistent concern over electricity affordability and difficulty tracking token usage, even during periods of subsidised access.

Importantly, FGDs reveal that learning and acceptance progressed rapidly once households gained hands-on experience. Over 80% of participants found eCooking easy to learn, and safety concerns were minimal. Younger household members adapted more quickly, while older cooks were more reluctant to abandon traditional methods. Despite this, overall attitudes toward eCooking were overwhelmingly positive, with high ratings for cleanliness, health benefits, and food taste. The reluctance to purchase appliances at unsubsidised prices, however, indicates that positive perceptions alone are insufficient to sustain adoption without aligned financing and delivery models.

5.2.2 Business adoption practices

ECooking adoption among businesses was faster, more intensive, and more strongly linked to productivity gains than among households. From the outset of Phase 2, businesses demonstrated a higher willingness to integrate eCooking into daily operations, driven by clear incentives related to time savings, cleanliness, and operational efficiency. Metered data shows that businesses consistently recorded higher daily electricity consumption for cooking than households, reflecting both larger cooking volumes and a stronger readiness to shift core cooking tasks to electric appliances.

FGDs indicate that businesses evaluated eCooking technologies primarily through a performance lens. Infrared stoves were again the most widely accepted, particularly for baking Somali injera and handling traditional cooking techniques without compromising food quality. EPCs were highly valued for reducing cooking time for bulk dishes, especially beans and stews, enabling faster service and greater throughput. Induction stoves, however, were largely relegated to secondary tasks such as boiling water or preparing sauces, due to pot incompatibility and perceived changes in food taste.

Unlike households, businesses were more willing to tolerate higher electricity consumption if it translated into efficiency gains. Phase 2 survey data show that while electricity costs increased for most participants, businesses were less deterred by this increase than households. FGDs suggest that businesses conceptualised electricity as a productive input rather than a household expense, making them more open to higher energy bills provided reliability and capacity were assured.

Unlike for households, stove use only increased a small amount in Phase 3 relative to Phase 2. Even when electricity was provided free of charge, these conditions, businesses continued to stack fuels, primarily due to appliance capacity constraints. Commercial-scale pots required for preparing large batches of food were often incompatible with the study appliances, forcing continued reliance on charcoal for peak-demand cooking.

Businesses also highlighted system-level constraints more explicitly than households. FGDs raised concerns about single-burner limitations, lack of redundancy during peak hours, and the absence of locally available spare parts and technicians. While training uptake was rapid and well-received, sustained adoption was seen as contingent on resolving these technical and supply-chain gaps. Notably, businesses expressed greater willingness to pay for eCooking appliances than households, but only if appliances could reliably replace charcoal stoves.

Overall, adoption patterns among businesses suggest a higher potential for rapid transition to eCooking, but only under conditions of adequate appliance capacity, multiple heating elements, and reliable after-sales support. Without these, eCooking risks remaining a partial efficiency tool rather than a full replacement for biomass fuels.

5.3 Perceived benefits and challenges of transitioning to eCooking appliances in Sheder

5.3.1 Household perspectives

Perceived benefits

Across Phase 2 and Phase 3, households consistently reported strong perceived benefits from using eCooking appliances, particularly in relation to health, cleanliness, and time use. Survey responses and FGDs reveal that the absence of smoke and ash was one of the most immediately valued improvements. Participants frequently linked eCooking to better indoor air quality and reduced physical discomfort, a perception reinforced by the near-universal reporting of improved cleanliness and reduced exposure to irritants during cooking. These perceived health benefits were also often framed in terms of daily lived experience, such as reduced eye irritation, fewer headaches, and a more comfortable cooking environment.

Time savings emerged as another key benefit, particularly for specific appliances and cooking tasks. Cooking diary data show reductions in both cooking time and fuel procurement time during Phases 2 and 3, with the largest perceived gains reported by infrared and EPC users. Households reported using the time saved for socialising, caregiving, and rest, suggesting that eCooking benefits extended beyond efficiency into broader well-being. Importantly, these time savings were perceived even when households continued to stock fuels, indicating that partial adoption still yielded tangible advantages.

Ease of use and safety were also perceived positively. Over 80% of participants reported that learning to operate eCooking appliances was easy or very easy, a finding echoed in FGDs where users described rapid familiarisation following training. Concerns commonly associated with new technologies, such as fear of electric shock or appliance damage, were relatively minor. Participants expressed confidence in operating temperature controls and reported few issues with stability, noise, or unpleasant smells during cooking. This suggests that behavioural barriers related to fear or mistrust of electric cooking were limited once hands-on experience was provided.

Food quality perceptions further reinforced acceptance. All appliance types received high ratings for taste and smell, with EPC users in particular noting improvements in flavour due to the absence of smoky residues. While eCooking did not fundamentally alter dietary patterns, Phase 3 surveys indicate that some households experimented with new dishes during periods of free electricity, signalling a degree of culinary flexibility and curiosity once constraints were relaxed.

Perceived challenges

Despite these benefits, households identified several challenges that constrained deeper adoption. The most frequently cited challenge across surveys and FGDs was the limited capacity and size of the appliances. Many households reported that study stoves could not accommodate large pots needed to cook for extended families, forcing continued reliance on charcoal for main meals.

Affordability concerns remained salient, even when electricity was subsidised. While Phase 3 demonstrated that free electricity dramatically increased usage, most participants indicated little willingness to purchase appliances or pay for electricity at unsubsidised prices. This perceived economic risk was exacerbated by difficulties in tracking electricity token usage, which undermined users' ability to predict costs and manage spending. As a result, electricity was often viewed as a potentially expensive and uncertain input, limiting households' confidence in relying on it for essential daily cooking.

Maintenance and after-sales support emerged as another major barrier. Households consistently reported poor availability of spare parts, compatible cooking pots, and trained technicians within or near the camp. This challenge was perceived as more severe than operational difficulties, as participants feared that appliance failure would leave them without recourse. The inability to easily move some appliances within the home further reduced flexibility, particularly in crowded living spaces.

Cultural and functional considerations also shaped perceived challenges. Certain cooking processes, such as long boiling, steaming, baking, and especially the preparation of injera, were viewed as difficult or impossible with some appliance types. Although infrared stoves performed better in this regard, many participants still perceived traditional stoves as more versatile and socially embedded, enabling multitasking, parallel cooking, and communal food preparation during religious and celebratory events.

5.3.2 Business perspectives

Perceived benefits

For businesses, perceived benefits of eCooking were closely tied to productivity, efficiency, and cleanliness. FGDs consistently highlighted time savings as a central advantage, particularly for EPCs, which were praised for reducing cooking durations for bulk dishes.

Cleanliness and improved working conditions were also highly valued. Business cooks reported substantial reductions in smoke, ash, and soot, leading to a more pleasant and professional kitchen environment. These improvements were perceived to enhance worker comfort and reduce health-related disruptions, even though thermal comfort benefits were sometimes offset by the loss of biomass stoves as a heat source during colder periods.

Food quality perceptions varied by appliance type but were generally positive for infrared stoves and EPCs. Infrared stoves were particularly valued for their ability to support traditional baking practices, including Somali injera, without compromising taste or texture. EPC users reported improved consistency and flavour for stews and beans, while induction stoves were often criticised for altering taste due to cookware limitations.

Unlike households, businesses were more willing to view electricity as a productive input rather than a household expense. Survey data indicate that businesses were more tolerant of increased electricity costs during Phase 2, provided these costs were offset by efficiency gains and faster service delivery. This framing positioned eCooking as a potential income-enhancing technology rather than merely a cleaner alternative.

Perceived challenges

Despite higher acceptance, businesses also faced significant challenges that limited full transition to eCooking. The most critical barrier was insufficient appliance capacity. Commercial cooking requires large pots and simultaneous preparation of multiple dishes, needs that were not adequately met by single-burner, household-scale appliances. FGDs reveal that this mismatch forced businesses to continue stacking fuels, particularly during peak hours, even when electricity was free.

Pot compatibility was a major constraint, especially for induction stoves, which could not accommodate commonly used commercial cookware. This not only restricted adoption but also increased perceived risk, as replacing pots represented an additional upfront investment. Businesses also raised concerns about the lack of redundancy; reliance on a single electric stove without a backup option was seen as risky in a commercial context where service interruptions have direct financial consequences.

System-level concerns were more pronounced among businesses than households. Participants expressed anxiety about electricity reliability, peak-load management, and the potential for outages during high-demand periods. Although Phase 2 surveys suggest that most users did not perceive a significant decline in electricity quality, the fear of disruption remained a psychological barrier to abandoning charcoal entirely.

Finally, maintenance and after-sales support were viewed as critical for sustained adoption. Businesses emphasised the need for locally available technicians and spare parts, noting that downtime due to appliance failure could directly affect income. While training was well received and quickly absorbed, businesses made it clear that skills alone were insufficient without an enabling support ecosystem.

5.4 Scalability potential of eCooking in Sheder

The divergence between household and business adoption patterns suggests the need for differentiated intervention strategies. While households prioritise affordability, versatility, and compatibility with large family meals, businesses prioritise efficiency, capacity, and reliability. Recognising and designing for these distinct adoption logics is critical for scaling eCooking in protracted displacement settings such as Sheder.

Therefore, while acceptance of the eCooking appliances was consistently high, their scalability depended more on the alignment between appliance design, financing mechanisms, and the economic realities of households and businesses in a protracted displacement context. Evidence from the intervention and exit phases suggests that demand for eCooking exists, but that it is highly price-sensitive and contingent on risk-mitigating delivery models rather than conventional market-based sales.

5.4.1 Household scalability and willingness to pay

Household purchasing behaviour at the end of the study provides a strong indicator of latent demand when affordability barriers are partially addressed. Of the original treatment group, 56 households elected to purchase their assigned eCooking appliances at subsidised prices. Only three households dropped out of the programme, one from each appliance group, and just one participant returned her appliance, citing insufficient stove size for her large family. This low attrition rate suggests that, once appliances met minimum functional expectations and were financially accessible, households were willing to commit to continued use.

However, this revealed willingness to purchase stands in sharp contrast to stated WTP at unsubsidised prices. Across all appliance types, the majority of participants reported little or no intention to purchase eCooking appliances at full market cost. Survey data show that while many households expressed positive WTP ranges in principle, these values fell well below prevailing market prices once subsidies were removed. This gap between perceived value and market cost reflects both constrained household incomes and high sensitivity to financial risk in a context where energy expenditures are already closely managed.

Crucially, the study indicates that households evaluate affordability not only in terms of appliance price, but also through ongoing and uncertain electricity costs. Difficulties tracking token usage and predicting monthly expenditure undermined confidence in eCooking as a reliable primary cooking solution. As a result, even households that experienced clear time and health benefits remained reluctant to assume full financial responsibility without protective mechanisms. This explains the strong preference for pay-as-you-go (PAYG) models observed in the exit survey, which were favoured by over 80% of participants, while outright purchase, microfinance loans, and lease-to-own schemes were overwhelmingly rejected.

From a scalability perspective, these findings suggest that eCooking adoption among refugee households is unlikely to scale through conventional retail or credit-based approaches. Instead, models that reduce upfront costs, smooth cash flow, and limit downside risk, such as PAYG, appliance-as-a-service, or heavily subsidised entry pricing, are more consistent with household decision-making logics in Sheder. Importantly, the high uptake at subsidised prices indicates that subsidies may be a necessary transitional mechanism to establish eCooking as a credible alternative to biomass fuels.

5.4.2 Business scalability and commercial viability

Businesses in Sheder demonstrated a different, though complementary, scalability pathway. Compared to households, businesses exhibited higher tolerance for electricity costs and stronger alignment between eCooking adoption and income generation. FGDs indicate that business

users conceptualised electricity as a productive input, and were more willing to pay higher tariffs if eCooking appliances delivered measurable efficiency gains, faster service, or improved food quality.

Nevertheless, scalability among businesses is constrained by technical rather than purely financial factors. Commercial cooking volumes exceed the capacity of household-scale appliances, and persistent fuel stacking during peak periods reflects a mismatch between appliance design and business needs. While businesses expressed higher WTP than households, this willingness was conditional on access to larger-capacity appliances, multiple burners, and compatible cookware. Without these adaptations, businesses viewed eCooking as a supplementary efficiency tool rather than a full replacement for charcoal.

Business model preferences further reveal this distinction. While businesses were less resistant to outright purchase than households, they still favoured flexible payment arrangements and expressed concern about maintenance, downtime, and access to spare parts. This points to the importance of bundled service models that integrate appliance provision, technical support, and predictable electricity pricing. For businesses, scalability is therefore closely tied to the reliability of both appliances and the minigrid, as interruptions directly translate into lost income.

5.5 Implications for delivery models and scale-up

Therefore, the scalability of eCooking in Sheder hinges on differentiated delivery strategies for households and businesses. For households, the combination of high adoption under subsidy, low dropout, and minimal returns indicates strong acceptance once affordability thresholds are met. However, the sharp decline in WTP at unsubsidised prices implies that market-based scaling without continued financial support is unlikely in the short to medium term. PAYG models, particularly those administered by trusted humanitarian actors, offer a promising pathway, as they align with household preferences for flexibility, predictability, and low financial risk.

For businesses, scalability depends on moving beyond household-scale technologies toward appliances designed for commercial use. Higher WTP and stronger productivity incentives suggest that businesses could anchor demand for eCooking within the minigrid, potentially supporting cross-subsidy models. However, this requires deliberate planning to ensure grid capacity, appliance durability, and after-sales service.

The study also highlights the value of revealed behaviour overstated preferences in assessing scalability. While surveys indicated widespread reluctance to purchase appliances outright, actual purchasing decisions under subsidised conditions tell a more optimistic story. The fact that 56 households chose to buy their stoves, and that only one returned an appliance due to a clearly articulated functional limitation, demonstrates that well-designed subsidies can convert positive perceptions into adoption.

The study demonstrates a clear latent demand for eCooking in Sheder. When paying for electricity under market-based conditions, participants used the appliances for around a third of cooking activities, significantly reducing charcoal use and resulting in time and financial savings. When economic barriers were removed, participants significantly increased their use of electric appliances, particularly infrared stoves, which saw near-total displacement of charcoal.

The infrared stove emerged as the most adopted technology due to its compatibility with existing cookware and ability to prepare all local foods, including injera. In contrast, EPCs, while efficient, were limited by pot size, and induction stoves faced significant resistance due to pot incompatibility and perceived changes in food taste. This highlights that successful scaling requires technologies that match local culinary practices and household sizes.

Findings also demonstrated notable divergence between household and business adoption patterns, pointing to the need for differentiated strategies. Businesses demonstrated a higher tolerance for electricity costs when linked to productivity gains, but were constrained by the limited capacity of household-scale appliances. Households prioritised flexibility, low financial risk, and the ability to cook for large families. The constraints were more significant for businesses than for households, resulting in similar levels of eCooking demand between the two groups, despite the exponentially large volumes of food prepared by the businesses.

The study also reveals that adoption is highly sensitive to upfront cost. Despite the widely perceived advantages of eCooking, willingness to pay full price for appliances was low. Almost all of participants purchased their stoves at an 80% discount at the end of the study. These findings demonstrate that subsidies and flexible payment plans will be necessary to cover and smooth the upfront costs of transitioning to eCooking appliances, but that strong levels of adoption are possible at the current tariff.

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